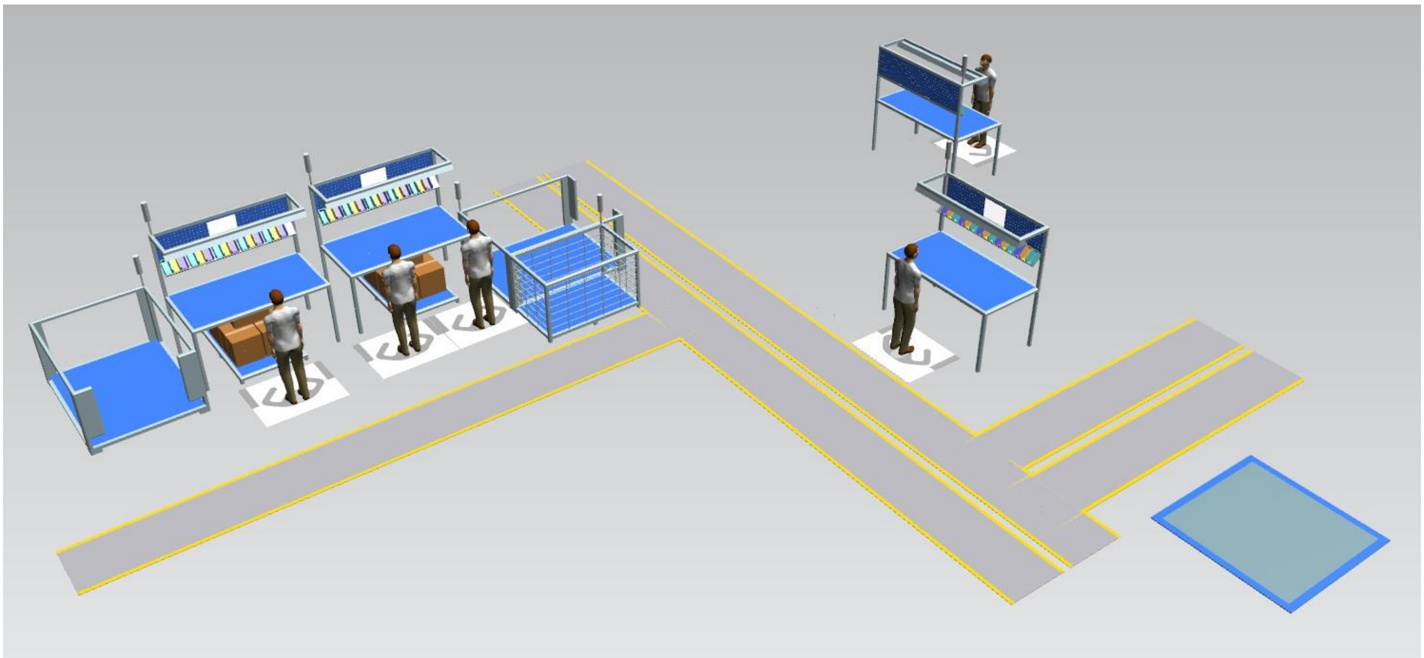

Managing Change When Improving Accessories Assembly Line According to Lean Six Sigma

A Feasibility Study at a Cable Distribution Cabinet Manufacturer

Master's thesis in International Project Management

BERWA KADER

Department of Architecture and Civil Engineering
Construction Management
CHALMERS UNIVERSITY OF TECHNOLOGY
Master's Thesis ACEX30
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MASTER’S THESIS ACEX30

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Cover: Assembly line layout (created by researcher in Tecnomatix)
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ABSTRACT

At ABB Kabeldon, the production of a disconnector required an evaluation. To account for a feasibility study that supported evidence-based decision-making. The aim was to discover how to manage affected resources. To explore and explain preventive arguments for the use of Lean Six Sigma. As an approach to foster inevitable gradual positive change within Accessories. What literature regarded as assembly line balancing was used to create a basis for problem solution. To propose suggestions for higher efficiency and more effectivity. Aligned with one-piece-flow production. Theoretical data encompassed management of operations, people, quality and the correlation between them. Empirical data were ethically deducted from interviews with Operators and team leaders in several departments. From surveys completed by team members throughout the organisation. From observations noted throughout the research project. The data was compiled in a knowledge framework. By combining the Six Sigma model known as SDMMAICS (Select, Define, Measure, Map, Analyse, Improve, Control and Sustain) and the change management model ADKAR (Awareness, Desire, Knowledge, Ability and Reinforcement). The assembly line was also analysed in relation to Lean principles. Namely, pull, flow, takt and zero defects. The results showed positive attitude towards Lean Six Sigma from team members. In general, and in particular at Accessories, it was discovered that more forces worked in favour of than against change. Root causes, wastes, benchmarking and the Q6 model were analysed to produce six suggestions for gradual positive change. Which were followed by suggested control mechanisms to ensure sustainable changes. Also, there was a discussion about the feasibility of a pilot project. In terms of technology, finances, legality, operations and time. Critical success factors to implement such a Lean Six Sigma project were established. Concerning commitment, understanding, experience of team members, collaboration, prioritisation, clarity, purpose and organisation. In conclusion, the suggestions were two-sided. On the one hand, they made it feasible to attain a greater level of production for the customer, relative to industry standards. On the other hand, they were enabling evidence-based decision-making, systematically, for future changes within Accessories. Finally, future research was recommended.

Key words: Gradual positive change, Lean, Six Sigma, SDMMAICS, one-piece-flow production, assembly line balancing, ADKAR, learning.

Hantering av förändringar vid förbättring av tillbehörsproduktion i enlighet med Lean Six Sigma

En förstudie hos en kabelskåpstillverkare

Examensarbete inom mastersprogrammet internationell projektledning

BERWA KADER

Institutionen för arkitektur och samhällsbyggnadsteknik
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SAMMANFATTNING

På ABB Kabeldon behövdes produktionen av ett frånskiljningsdon utvärderas för att utgöra en förstudie som skulle bidra till faktabaserade beslut. Syftet var att upptäcka hur berörda resurser skulle hanteras. Att utforska och förklara förebyggande argument för användandet av Lean Six Sigma som ett förhållningssätt. För att främja oundvikliga, ständiga förbättringar inom tillbehörsavdelningen. Det som belystes av teorin gällande löpande band användes för att skapa en grund för problemlösning. För att föreslå förbättringar för högre effektivitet och bättre verkningsgrad. I linje med enstycksproduktion. Kritiska framgångsfaktorer för att genomföra ett sådant Lean Six Sigma projekt etablerades. Teoretiska data omfattande hantering av processer, människor, kvalitet och sambandet mellan de. Empiriska data härleddes etiskt från intervjuer med operatörer och arbetsledare från flera avdelningar. Från enkäter ifyllda av medarbetare inom hela organisationen. Från observationer noterade igenom hela projektet. Data var sammanställd utifrån ett ramverk för kunskap. Genom att kombinera Six Sigma modellen, känd som SDMMAICS (Välja ut, definiera, mäta, kartlägga, analysera, förbättra, kontrollera och upprätthålla), med förändringshanteringsmodellen ADKAR (Medvetenhet, önskan, kunskap, förmåga och förstärkning). Monteringsbandet analyserades i relation till Lean principer. Nämligen, drag, flöde, takt och noll-tolerans mot defekter. Resultaten visade på positivt inställda medarbetare gentemot Lean Six Sigma. Generellt men främst inom tillbehörsavdelningen upptäcktes fler krafter för förändring än mot förändring. Rotorsaker, slöseri, utvärdering av andra avdelningar och Q6 modellen analyserades för att föreslå förbättringar, vilka följdes av kontrollmekanismer för att försäkra hållbara förändringar. Därutöver, diskuterades genomförbarheten av ett pilotprojekt angående teknologi, ekonomi, legalitet, processer och tid samt de åtta kritiska framgångsfaktorerna om engagemang, förståelse, erfarna medarbetare, samarbete, prioritering, tydlighet, syfte och organisering. Slutsatsen var att förbättringsförslagen hade två sidor. Å ena sidan gjorde de det genomförbart med en uppgradering av produktionen, för kunden, relativt till industristandarden. Å andra sidan möjliggjorde de systematiska, faktabaserade beslut för framtida förbättringar inom tillbehörsavdelningen. Avslutningsvis, rekommenderades framtida forskning.

Nyckelord: Ständiga förbättringar, Lean, Six Sigma, SDMMAICS, enstycksproduktion, löpande band, balansering, ADKAR, lärande.

CONTENTS

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The study was executed thanks to organisational efforts by ABB Kabeldon, in Alingsås, and Chalmers University of Technology, in Gothenburg. For five months, I had the opportunity to have insight in operations done at a renowned manufacturer. Whom lived up to the expectations of professionalism and quality. Both within the team I found to be committed and encouraging. And within a complex production site which I found to be worthwhile exploring.

Thanks to Fredrik Karlsson, as a Production Development Specialist at ABB Kabeldon, I met several important stakeholders and he introduced me to the departments and their processes, respectively. As a supervisor he helped me to stick to the plan and provided useful tools, enhancing the project. Which I am truly grateful for.

Without the operators and team leaders managing shop floor there would be no empirical data. I appreciate their involvement and sharing of highly qualified experience and knowledge. I am also thankful for the supervision of Mathias Petter Gustafsson at Chalmers University of Technology. He pushed me in the right direction and aided me in making the study credible. In addition, the project would not be possible to initiate and pursue without the welcoming support of Fredrik Axelsson, R&D Manager at ABB Kabeldon.

Finally, I would like to express gratitude towards my family who cared about and supported me when I found it difficult to progress. They have always been a great source of strength, dedication and purpose for studies from the first day of school.

Göteborg, January 2020

Berwa Kader

LIST OF ABBREVIATIONS

PPM	Parts per million: a dimensionless number calculated as (number of defect units/number of supplied units) x 1,000,000.
FPY	First pass yield: number of acceptable units of products finished without scrap or rework divided by total units of products coming into the process
OMS	Operations management system
KPI	Key performance indicator
PPS	Practical problem solving
PDCA	Plan, do, check, act
SOI	Standardised operating instructions
ROI	Return on investment
SDMMAICS	Select, Define, Measure, Map, Analyse, Improve, Control, Sustain
DMAIC	Define, Measure, Analyse, Improve, Control
WIP	Work in progress
NCC	Nonconformity cost
SMDS	Single-model, deterministic, straight-type
SALB-2	Simple assembly line balancing type 2
QW	Quality Wins
CT	Cycle time

1 INTRODUCTION

Within this chapter the background of the study is explained. Along with the purpose, aim and objectives, research questions and demarcations as well as the problem at hand. Understanding the subjects is imperative to have realistic expectations on the problem solution process. The chapter is ending with an overview of all chapters within the report.

1.1 Background

ABB Kabeldon is a medium-sized enterprise within a large organisation which develops, markets and sells coatings, tracks and fuse switch disconnectors for cable distribution cabinets and other low voltage solutions. ABB Kabeldon has an Accessory assembly line to produce constructions supplementing the department of Fusegears and Switches. Comprising 8 individuals who manually assembles toggles and accessories to feature lists and cable distribution cabinets. Improvements of the operations here is what interests me. That is, how the team develops, pursues and maintains the ever-flowing operations in order to manage top-notch production. Even more interesting is to find out whether it is possible to improve current operations and make an impact on the department along with the working environment of its Operators.

It leads us to the question of necessity; why should the project stakeholders invest in a feasibility study? Tenera & Pinto (2014) claim that business is becoming more and more complex and harder to compete within. Therefore, organisations are to come up with solutions to drive their day-to-day business towards more profitable settings, creating better products with lower financial aids (Rosa and Broday, 2018). Alexander et al. (2019) concurs, stating even minor pauses in improvement or not increasing earnings is debilitating. When the external environment changes, the organisation must adapt and respond to higher demands, global economies and improved competitors (Drohomeretski et al., 2014). Following a confidential philosophy and choosing the right strategy followed by suitable operations methodology to improve business are therefore critical for successful management. Consequently, ABB has turned their hearts and heads to Lean Six Sigma as a way of attaining competitive advantages over competitors in the manufacturing of accessories for their galvanized cable distribution cabinets.

Lean Six Sigma benefits many companies in terms of financial savings, fewer defects reported, better use of time as well as higher level of quality and productivity (Anbari & Kwak, 2006). Impeding factors are as important such as the underlying operations strategy, with its principles, concepts and tools, when changes are anticipated. If the managers are not engaged in projects, changing the culture of the department, LSS is advised not to be implemented. The people conducting training of change management are sought over to successfully improve the department. Moreover, wanting more than possible out of a project which has been chosen on false premises amongst other reasons leads to discontinuation of an LSS project (Sony et al., 2018).

Electrification Products, Protection & Connection operations management system (EPPC) is ABB's way of working with LSS to manage quality and operations. The vision at the department of Electrification is to implement a model (Q6) for Operation Excellence in order to recognise deviations and deficiencies using quality circles, defect classification, visualisation of performance, standardised modus operandi, competence provision and standardisation.

In addition, there is a desire for development, value optimisation and higher quality of each accessory to meet market demands and fulfil customer needs. To pin-point specific aspects that are consistent with these intentions requires systematic, factual knowledge on each matter. Thus, ABB Kabeldon needs to invest in development projects such as a pilot project that may be the result of this feasibility study to stay aligned with company vision and strategy.

However, there is a need for heads-up when an organisation such as the central figure of this feasibility study is in this for the long run. Critical success factors such as top management commitment, training and education, communication, customer focus, organisational culture, employee involvement, teamwork, supplier focus, understanding equipments and techniques and organisational infrastructure (Sreedharan et al., 2017) are important to emphasize in order to gain trust in the philosophy and change the organisation for the better through a proactive approach to gradual positive change.

Sony et al. (2018) state that, critical failure factors is as significant to investigate. In some cases, reflecting the critical success factors. There are several reasons for dismissing LSS to foster the philosophy. For example, unsupportive and uncommitted top management. This means that benefits are not attained which may harm the organisation instead.

1.2 Purpose

The purpose is to investigate the current situation of an assembly line. It is also to highlight areas for improvement and possibly produce a number of gradual positive changes which can make it more efficient, in terms of better ways of doing things instead of the current ways of doing, and/or effective, in terms of better things to do instead of the current doings.

1.3 Aim and objectives

The aim is to identify ways of making the assembly line sufficient and improve the current process that is undergone by the Operator. In doing so, affecting procedures, norms and responsibilities at the department.

The following objectives are pursued:

- To discover how to manage affected equipments and more importantly human beings.
- To explain preventive arguments for the use of Lean Six Sigma as an approach to foster inevitable change at the accessory line within six months.
- To explore ways for gradual positive changes when assembling accessories to fusegears and switches.

1.4 Research questions and demarcations

The following questions directs the study towards the aim and objectives. They are answered methodically as a result of analysis and discussion of collected empirical and theoretical data.

Research question Q1:
What is the literature representing regarding assembly line balancing?

Research Question 2:
How can the Accessories department improve towards a one-piece-flow production?

Research Question 3:
What are the critical success factors for such a Lean Six Sigma project?

Lean Six Sigma (LSS) is relatively new in research. This ultimately leads to restricted knowledge in relation to successful implementation. Also, strategy definition, previous comparative analysis and historical description of development of LSS are limited (Alexander et al., 2019). However, the project focuses on only LSS even though the concepts of Lean and Six Sigma are presented separately.

Operation strategy is of importance when conducting projects that deal with gradual positive changes. However, the operations' strategy are only mentioned. The company have a strategy for improving operations which is not scrutinised. They have included Total Quality Management which makes the study too broad if included. But the OMS is however included to approach the problem holistically.

It is harder to produce gradual positive changes and gain wisdom if the scope is too broad. Therefore, the focus of this study is not on Fusegears and Switches even though their assembly line is closely related to Accessories' assembly lines.

Due to lack of public access not all data are shared and viewed by the readers. Because the company has reasons to restrict access to sensitive data and withhold vital data due to competitive and security reasons.

1.5 Problem description

The problem area is within the operations at the Accessories assembly line. Here lie four work centres divided into seven workstations. These workstations are operated independently by Operators who perform tasks according to a work plan. The assembly line system consists of Operator(s), equipments, manual assembly lines and instructions. There is no operations management system (OMS) ensuring, checking and maintaining consistent quality. This leads to quality deficiencies and deviations that may not be managed accordingly. There are waste that lead to loss of resources such as time, money and quality of work for the Operator and by the Operator. The operations are without balanced takt and with uncertain lead time, independent of other workstations and work centres. There is insufficient data to use for an analysis prior to decision-making with regards to desired changes.

One of the products is Product A which is assembled manually. There are clear instructions on how to assemble it. The product is assembled by a neighbouring work centre but have previously been owned by Accessories. Since it is a suitable product for the application of the new EPPC OMS, explained below, it may return to the department as a result of this feasibility study.

The production team is not used to working according to a system. However, they are used to gradual positive changes applied to respective workstation. These changes are ergonomic, affecting norms, behaviour and shared mental models (Hayes, 2007: 65).

1.6 Chapter overview

The thesis is divided into nine chapters, including references at the end. Followed by appendices containing useful information for the creation of the study. Figure 1 illustrates the process of the thesis and how subprocesses are interrelated.

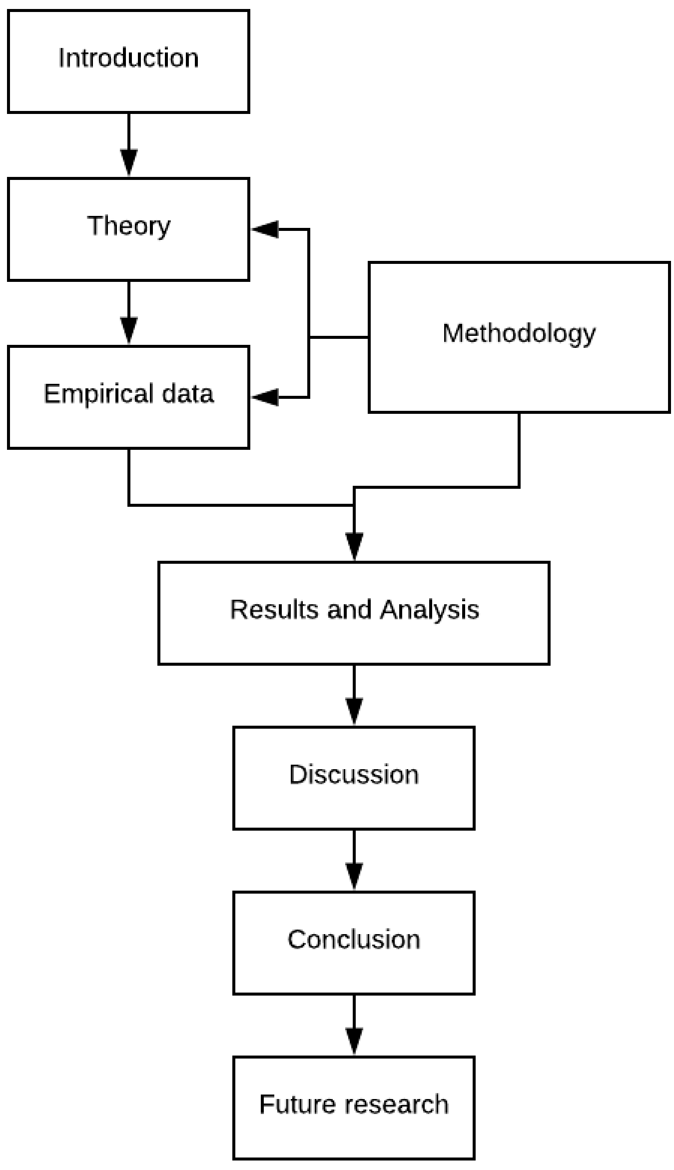

Figure 1. Chapter overview (created by researcher).

2 THEORY

This chapter explores the subject theoretically. A literature review of previous research is made. To form theoretical knowledge that prescribes relevant subjects to consider. Mainly, how to systematically manage operations and the people operating the process to produce quality.

2.1 Literature review

Literature is studied on a micro level. By searching Chalmers University of Technology's Library Discovery Service and Google Scholar encompassing multiple content providers. Such as ScienceDirect, Elsevier and McGraw-Hill. Keywords such as Lean, Six Sigma, continuous improvement, change management, production, success factor, assembly line balancing, assembly line theory are used to find relevant journals, books and eBooks. By reading one of these sources, more relevant sources are found by browsing each journal's reference list.

The knowledge framework also aids the direction of the problem solution process. The theoretical data collection process is inductive by gathering data to provide a theory, or more accurately, a basis for one or more gradual positive changes. It is collected by systematically reviewing previous research. Research that is proven credible with valid, generalisable, reliable and/or transferable discussions and results. (O'Leary, 2017: 67-68). The goal is to approach the literature with a transparent, verifiable and replicable approach. To minimise bias and error, creating a context for results of a new study and depicting a representative picture of the research area. Within reach for direct and indirect stakeholders. Mainly, by synthesizing what previous theories and research present from different perspectives relevant to the case.

2.1.1 Managing operations

Slack et al. (2016: 14) describe the setting of operations and how the input-transformation-output process affects the accessory assembly line, see Figure 2. Internal operations are part of something larger and is connected to other operations as well as processes at Fusegears and Switches and other departments.

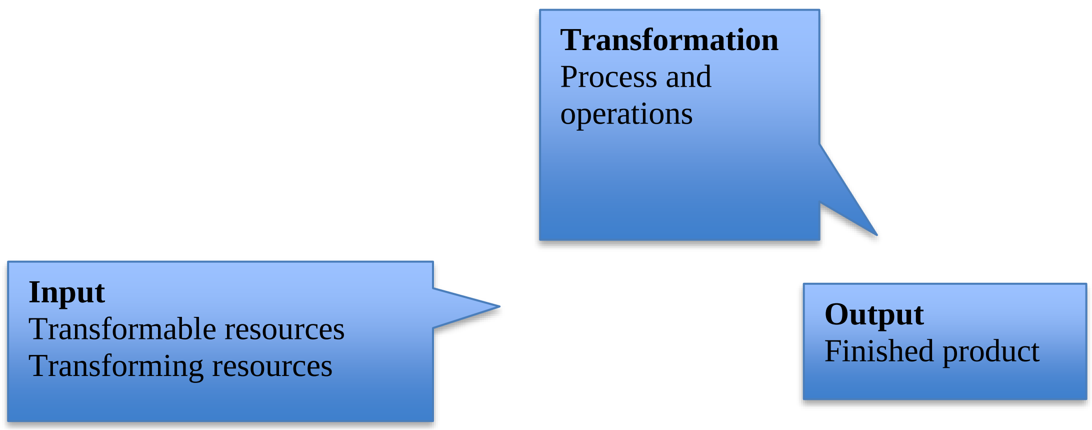

Figure 2. Input-Transformation-Output process (Slack et al., 2016: 14).

The operations are defined in terms of volume, variety, variation and visibility according to Slack et al. (2016: 22). Operations management uses people and technology to efficiently and effectively assemble Product A that meets current customer requirements (Slack et al., 2016: 32).

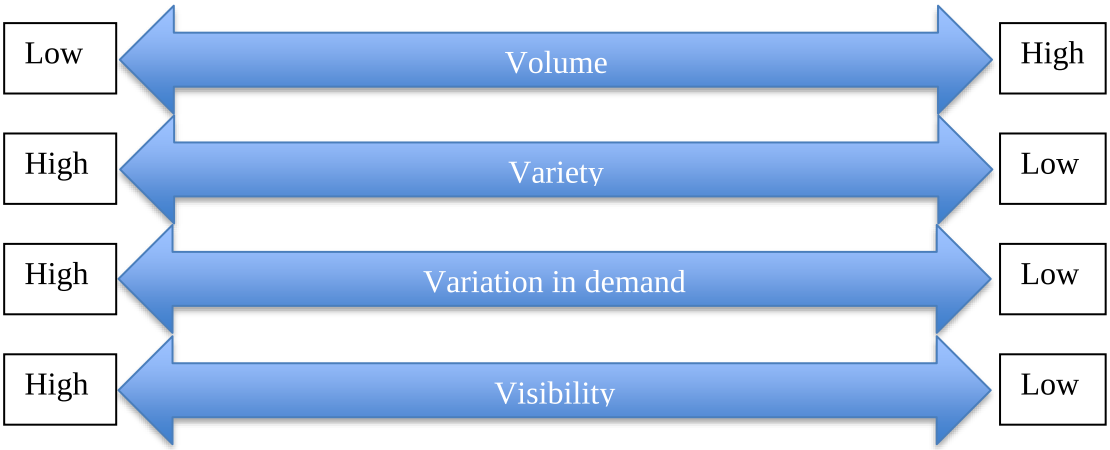

Figure 3. Operational dimensions (Slack et al., 2016: 26).

Consequently, the costs are reduced according to Slack et al. (2016: 26) since there are high volume, low variety, low variation in demand and low visibility, see Figure 3. To manage the operations is thereby to plan how the accessory line is to function, design collaboration of equipment and people, plan and control how resources goes through a process and how this process coincides within the network. Subsequently improving the overall performance. Managing the operations with the four V's in mind creates complexity. Managed by people who are affected by the operations in terms of input and output.

2.1.2 Managing people

People need to be led and/or managed in an organisation. Especially in times of change. These people are affected by individual/s in a position to influence others and/or operations by asserting power. Power is derived from both soft and technical skills. From political position in relation to others. From control over resources and his or her organisational position. From being relevant to the process and gradual positive change.

These people are the stakeholders who can break or make the change project. They have a vested interest in the project and requires to be managed properly. They require a straightforward approach of change management. The attitude towards change needs to be set regarding a step-by-step change. The changes need to be defined and dealt with according to a plan (Hayes, 2007: 101).

> *"This executive worldview is built around the necessity to maintain an organization's financial health and is preoccupied with boards, investors, and capital markets. Executives may have other preoccupations, but they cannot get away from having to worry about the financial survival and growth of their organisation." (Hayes, 2007: 155)*

Furthermore, the communication that underlies management of people is as critical as the people themselves. Poor communication leads to slow change process with little innovation or uneven gradual positive change. It is affected by the direction knowledge is communicated, as in the understanding of stakeholder management. To go about communicating with the stakeholders it is fundamental to plan. According to Hayes (2007: 181-182) there are two approaches that suit the context of this study.

Firstly, it is helpful to tell and sell based on primarily technical data that the chosen way of managing change is predetermined by management. Also, it is to handpick clusters of information that management has chosen as relevant to the different stages throughout the process of change. Even though it is an effective way of communicating there is a downside. People feel left out and silence between stakeholders is interpreted differently. Resulting in different understandings of definitions, presumptions, desires, norms, objectives, the outcome on relationships and individuals power positions.

Secondly, it is by identifying and replying. Management prioritises people over finances, technical challenges and operational obstacles. The assumption is that Operators are well-adjusted to changes and know where they stand. Even though that may not be the case. By listening and responding proactively, people feel included throughout the change process.

Moreover, a key performance indicator to effective communication is motivation. Even though it is difficult to assess, an Operator is more inclined to support the organisation when s/he is motivated to support change than the opposite. Which can instead lead to resisting to change the organisation.

To be able to reroute reactions to change positively is to understand resistance of change. Namely, due to interest in benefiting self's own power and influence over that of the organisation. Due to misunderstanding the change initiative and its purpose as well as objectives. Because of differently assessing the situation by stakeholders and management in relation to costs and hands-on information. Because of low, psychological tolerance for change making a stakeholder unable to adapt and overcome gradual changes.

How motivation is induced in stakeholders hinge on expectations. The effort a stakeholder must put in is dependent on his or her expectations on performance. Not only performance evaluated by management but more critically expectation(s) on performance s/he has on himself or herself. Another type of expectations beneficial to communicate is expectations on the outcome of a stakeholder's performance.

Accordingly, motivation is increased by communicating with the stakeholders on a regular basis and/or during different phases of the change process. By utilising following methods stakeholders are successfully approached. To increase positive attitude and make use of a stakeholder's power and influence on the change project and its agreed norms, practices and beliefs. (Hayes, 2007: 216-220)

Education and persuasion

By educating one or more stakeholders with facts and information about the purpose of the change s/he can understand the circumstances. The art of persuasion is applied by creating a desire to change. Instead of being the one to resist change and known as a blocker of satisfaction, s/he becomes a sponsor or promoter of change.

Participation and involvement

Change is defined by the whole team instead of only a few, generating a common ground. By doing so everybody take ownership of the intended change and the process to get to the goal(s). Thus, manifesting the changes and making them last. Critical factors such as power, knowledge and ability to change are shared making people trust each other. Also, they are supported by believing in a change for the better in times of hardship. However, there is a risk of diminishing the technical understanding of a change project when people with inadequate or insufficient knowledge participates. More use of time is another factor which requires financial input.

Facilitation and support

All changes affect an individual psychologically. By providing support mechanisms throughout the change process s/he moves on effectively. Letting go independently based on fear or anxiety. By countering resistance on a psychological level, the stakeholder feels treated by respect and responsibly. Given appropriate time and support to truly overcome fear or anxiety making these feelings temporary. Evidently making the person more inclined to accept new practices.

Negotiation and agreement

By agreeing on the terms of change a stakeholder accepts the situation. Power and interests are thereby managed and exploited. Negotiation is a tool for amplifying support of change and disengage resistance of change. People see an opportunity to get what s/he wants or get rid of unwanted things that are apparent.

Direction and a reliance on explicit and implicit coercion

Management need to coerce power on inferiors. To increase the pace of change or force the person to undergo changes because that is what's best holistically. Withholding what somebody can get is an implicit way of coercing the individual to work for that object or subject. It results in retaliation or hate but is sometimes the only way to motivate people to do what is required.

2.1.2.1 ADKAR Change Management model

According to Hayes (2007: 10) as well as Slack and Lewis (2017: 237) change is either radical or gradual. In this feasibility study I focus on gradual positive change of the assembly line towards one-piece-flow production. The process is determined by many small steps in the same direction. The people are organised to follow directions by formal leadership in a methodical way towards predetermined goals. Focus is on taking small risks, doing things right often, quality and having the customer in mind. Gradual positive change

> *"involves individuals and groups accommodating to and experimenting with everyday contingencies, breakdowns, exceptions, opportunities and unintended consequences and repeating, sharing and amplifying them to produce perceptible and striking changes." (Hayes, 2007: 45)*

Change management is, according to Galli (2018), defined as

> *"the application of a structured process and set of tools for leading the people side of change to achieve a desired business outcome; it is both a process and a competency" (Galli, 2018: 124)*

In another study Galli (2018) reports that the process of change management is generally established as five phases, see Figure 4, in relation to project management. Firstly, an identification phase is experienced by the department and its stakeholders. Secondly, the change aspects are defined. Thirdly, the stakeholders are mapped, and people are managed. Fourthly, activities are undertaken, and the process is active. Finally, the changes are controlled and monitored to assure that what was planned is achieved and that deviations are reported for upcoming projects.

Figure 4. Generic process for managing change (Galli, 2018: 125).

Consequently, the ADKAR model is suitable for manufacturing settings such as an assembly line balancing problem because nothing will be produced if the Operator does not work. Nothing will change if s/he does not adapt to it. Informal groups can affect the LSS project and either break or make the change. ADKAR (Awareness, Desire, Knowledge, Ability, Reinforcement) has five objectives.

1. To make aware the necessity of change and the amplitude of it. Negotiation and agreement are important for this objective to motivate team members.
2. To illuminate the desire of this change and motivational factors that fuel the process. Participation and involvement are suitable communication techniques.
3. To produce knowledge of a strategy for change and what this means for everybody and everything. Education and persuasion are the right way to go towards this objective.
4. To outline the competencies and abilities that necessitates change on a regular basis. Direction and a reliance on explicit and implicit coercion is suitable communication technique.
5. To reinforce the people and operations in order to keep the outcome sustainable. Therefore, facilitation and support are appropriate communication methods to motivate team members to pursue the changes.

This model is suitable for changes that affect the people rather than the equipments and products. The Operators are in the spotlight from the beginning to the end. Even though the company is a medium-sized entity, the department is proportionally small consisting of 8 individuals and 4 work centres. Which makes ADKAR an appropriate choice based on the research of Galli (2018).

2.1.2.2 Learning organisation

Basically, the best way to manage change is by learning. By learning the new norms, practices and ultimately the new belief that fits the environment of a desired stage. Thus, a shared mental model is altered with the intention to produce gradual positive change. (Hayes, 2007: 65-66; Galli, 2018)

Ghosh, S. and Gagnon, R. J. (1989) assert a main success factor of an efficient and effective assembly line is the people operating it. Inherent is the paradox of efficient team members and happy team members. By being a learning organisation, the Operator is provided with encouragement leading to him or her operating the assembly line efficiently and effectively. Even though personal development is restricted. Since it is a socio-technical system the organisation must guard its team members. By immersing into an understanding of why Operators deviate in productivity. Broadly, due to variation in task times, effects of learning, absenteeism and quality level of the produced work. But also due to costs, training, supervision, defect correction.

According to Bergman and Klefsjö (2014) a learning organisation is

> *"…an organization skilled at creating, acquiring, and transferring knowledge, and at modifying its behaviour to reflect new knowledge and insights." (Bergman and Klefsjö, 2014: 409)*

When extending changes to organisational rules which affect a team member's behaviour *single-loop collective* learning is occurring. I.e. doing things better. This also does not require inquisitive thinking from the team member. But rather adaptation to the organisational setting and gradual positive change.

By going further to change shared mental models there is a *double-loop collective* learning. This in turn affects rules and consequently behaviour. I.e. Doing things differently or doing different things. At this stage it is important to constructively criticize organisational ideas, approaches and beliefs to reach an updated, desired setting. The role of the team is critical to successfully learn throughout the organisation and establish a shared vision to strive towards with a set of objectives. (Bergman and Klefsjö, 2014; Hayes, 2007: 61; Slack et al., 2016: 563)

2.1.3 Managing quality in operations

Quality is defined as "the totality of feature and characteristics of a product or service that bears on its ability to satisfy stated or implied needs." according to ISO 9000. In addition, it is argued that it is thought of as a process focusing on the overall achievement of the operations and managing the customer's expectations successfully (Harold, 2017: 699; Slack et al., 2016: 573).

When deciding on future, strategical actions it is important with facts (Bergman and Klefsjö, 2014: 40). Without facts, quality is put in the hands of chance. Products don't remain successful due to lack of investigation for development causes. Or lack of information and facts about the operations causing defects and deviations leading to variation. That is why there are improvement tools and management tools to make decisions based on evidence (Bergman and Klefsjö, 2014: 41).

Bergman and Klefsjö (2014: 24) claim that *"the wooing of the customer is never done"* when managing quality. Therefore, gradual positive change also known as continuous improvement is of interest to delve into. Drohomeretski et al. (2014) bases this statement on several other researchers work by claiming

> *"Continuous improvement is simple, easy to understand and requires a low investment; it is now considered one of the most efficient ways to increase the competitiveness of an organisation." (Drohomeretski et al., 2014: 804)*

Besides focusing on understanding quality, several opportunities arise when concentrating resources on gradual positive change (Rosa and Broday, 2018; Drohomeretski, 2014; Ortiz, 2006, p. 2). Lower operation costs, higher reliability, faster operations and more efficient adaptations to the environment. It also leads to a better product, greater service and smoother process. Gradual positive change as a way of managing quality is applied to meet the challenges of a business. Manufacturing costs affect quality if not controlled. As do customer satisfaction and how well the Operators and their activities work if not controlled properly. Subsequently, an OMS is established below to foster this mindset following philosophies, methods and tools.

2.1.3.1 Lean

Drohomeretski et al. (2014) claim that the journey of Lean is rooted in the World War II which resulted in devastation for Japan. Organisations had hardship being effective and people didn't know what to do. Over the years, the paradigm of operations management in relation to Lean has shifted from robustness to zero margins, from planning to flexibility, from resources utilisation to flow and from optimisation to gradual positive change (Slack et al., 2016: 498-528). Basically, to reduce costs and increase quality. When doing so, each problem is a chance for improvement (Slack et al., 2016: 506; Cannas et al., 2018). Thus, the people are doing the right things.

According to the EPPC OMS, Lean is usually simile to a house of activities consisting of four pillars. Each of the four principles are followed to achieve goals for each part of the department. Namely, the *flow* principle, the *takt* principle, the *pull* principle and the *zero defects* principle. All principles rest on the belief that Operators make products valuable for the customer by diminishing waste (Bergman and Klefsjö, 2014, p. 581; Slack et al., 2016: 499; Drohomeretski, 2014; Singh and Rathi, 2019; Sony et al., 2018). One side of the coin in Lean management is the wastes (Slack et al., 2016: 506; Sony et al., 2018). Waste in all shapes and sorts within the OMS are known as *muda* (waste). They do not add value to the operations nor the people. Waste because of inconsistency known as *mura* (unevenness). Also, waste because of *muri* (burden); overestimated level of basic skills and unmatched workload in relation to the Operator's capabilities.

The flow principle deviates from the traditional flow by creating synchronisation of all stations and people of the assembly line. The input of parts from one station to another is delivered in a timely manner based on the demand. Rather than basing deliveries on work in progress (WIP) (Slack et al., 2016: 502). Greater WIP is an obstruction for the Operator working on each operation when assembling Product A. Since many issues do not surface due to the big amount of WIP standing in the way of viewing them. One-piece-flow production which is central for this feasibility study is an example of the flow principle. Other than WIP, muda also causes useless movements. Muri causes potential Operator creativity which has not been taken advantage of.

The takt principle is based on the customer. Only when the customer demands a product is operations initiated. The Operator demands parts from the supplier and can begin the work. The customer pace set production rate and takt time is determined. The time aspect is examined. As quoted by Bergman and Klefsjö (2014, p. 581) Taiichi Ohno, founder of the Toyota Production System known for its Lean management, said

> *"All we are doing is looking at the timeline from the moment the customer giver to an order to the point when we collect the cash. And we are reducing that timeline by removing the non-value-added wastes." (Ohno, 1988)*

Subsequent waste because of muda is waiting in-between operations or during an operation. Also, the operations may be faulty or misused resulting in deficiencies on Product A.

The pull principle suggests that instead of pushing material from supplier towards the customer it is pulled from the customer. Through the workstations consisting of Operators. Bergman and Klefsjö (2014, p. 582) state that it is a "consumption-driven manufacturing". Mura leads to overproduction of Product A.

The zero defects principle concerns error prevention. Sorts of Examples using this principle are 5 Whys and Andon. A sort of waste due to muda is defects on Product A.

2.1.3.2 Six Sigma

Six Sigma was first practiced successfully by Motorola in the 1980s. The labour was concerned with finding faults and deviations e.g. defects to minimise costs and make operations more efficient. Thus, doing things right.

Managers on all levels were engaged in the daily work side by side with Operators. The organisation was structured to facilitate teamwork. Team members were educated and trained. (Singh and Rathi, 2019; Drohomeretski, 2014). Even today the same approach is used, however with project management as an addition to the framework of Six Sigma. Based on a multitude of definitions Six Sigma is defined as

> *"the implementation of a managed portfolio of process improvement projects, which uses a defined method to conduct projects by a specified Project Management routine, using project leaders with special project leader competencies." (Marzagao and Carvalho, 2016: 1508)*

By statistically approaching a problem it was more probable to find a beneficial solution, at the early stages of Six Sigma implementation. It was later portrayed as the DMAIC model, also defined by Sony et al. (2018). Becoming a statistical model for problem solving that is widely used in many industries, especially the manufacturing industry. Mainly, as a project exercised for three to six months. Covering all aspects of a project such as time, cost and scope to deliver quality.

2.1.3.3 Lean Six Sigma

According to Slack et al. (2016: 553) Six Sigma and Lean are both focused on gradual positive change over rapid changes even though Six Sigma is also suitable for greater changes such as the implementation of a complete OMS. Together the right things are done in the right way based on facts used by the right people. This has been done for almost 20 years primarily in manufacturing organisations.

LSS has benefited many companies in terms of financial savings, fewer defects reported and better use of time. Decreased cycle time (CT) of the process as well as higher level of quality and productivity on operations have been made. Compared to other synergies conducting gradual positive change, a combination of Lean and Six Sigma is the best match (Drohomeretski et al., 2014).

The department can benefit from better productivity from the equipments and people. Finances can be decreased saving money for other improvement projects. Customers are more satisfied with faster delivery of order due to decreased CT. WIP and space utilisation are diminished due to standardised operations. People are taken care of with less efforts needed both physically and psychologically. They are also given attention to by providing a change of culture which they can be part of in defining.

There are however challenges to overcome when implementing an LSS methodology. Challenges arise when processing the change. Communicating with people with the aim to change behaviour inevitably leads to conflicts which are challenging to resolve. Lean focuses on simplifying operations and improving behaviours independent of the OMS, i.e. doing the right things. Six Sigma focuses on system improvement, i.e. doing things in the right way. Thus, the challenge is combining the two approaches successfully, addressing both the organisational strategy and the Operators' modus operandi. In addition, determining a realistic timeline and budget for the LSS project is also a challenge since Lean requires less time and money than Six Sigma.

Impeding factors are as important and should not be neglected such as the underlying operations strategy with its principles, concepts and tools. The Operators must concentrate and prioritise the project to adapt to the changes. They must also have all relevant data communicated to them. And if the managers are not engaged with LSS projects in relation to facts, ultimately changing the culture of the department, it is advised not to implement LSS (Rosa and Broday, 2018; Anbari and Kwak, 2006).

2.1.4 Assembly line balancing

To pave the way for gradual positive changes it is critical to understand assembly line balancing. It is the art of creating and maintaining a steady pace of production with minimal waste. According to Cannas et al. (2018) an assembly line is

> *"a set of workstations positioned in a definite order and connected by transport mechanisms (e.g. conveyors). Materials pass through workstations where different tasks are performed, following specific precedence relationships to assemble the final product." (Cannas et al., 2018: 3914)*

Levelling is another term related to assembly line balancing (Slack et al., 2016: 517). The wanted batch is produced according to a work schedule. Instead of producing in large batches the goal is to produce in an even pace of the same output each day. Large batches lead to higher WIP making it harder to understand how people are performing in relation to demand. This is possible because once the output is dependable, what needs to be done is to check the time of the day to see where in the process the people will be.

Sivasankaran and Shahabudeen (2014) as well as Ghosh and Gagnon (1989) claim that an assembly line system is constituted by a network of operations performed under a time period resulting in a CT. Task time can be classified as probabilistic, depending on chance, or deterministic, depending on the inputs.

In this study of assembly line balancing, the objective is to maximise the production rate by minimising the maximum of the sum of the task times of each workstation. This is presented as a type 2 problem (SALB-2). Here the strategy is to delegate the tasks, which are in a predetermined precedence network which should not be affected, to the Operators stationed at the workstations and decreasing the CT. By pacing the Operator to keep up with the CT has a fallout of lower output compared to an unpaced line. Assembly line balancing is also dependent on the type of line.

Research is distant from the reality of assembly lines. Mathematical models consisting of exact and approximative methods do not fully integrate with real-life settings. Hence, they are disregarded. Heuristics such as algorithms and programming models consume time and money without guaranteeing problem solution. Therefore, a need for simplified models has emerged which LSS combined with ADKAR fully counters. However, for proper decision-making based on a comprehensive strategy there are several factors to process: (Cannas et al., 2018; Ghosh and Gagnon, 1989; Ham and Park, 2014; Qattawi and Madathil, 2019)

- There is a focus on output according to literature on operations management
- The line type is defined according to assembly line literature
- Process and equipment are considered according to LSS
- Workstation(s) is considered according to LSS
- Activities related to tasks are considered according to LSS
- The Operator is considered according to ADKAR
- The timeframe for tasks is considered according to ADKAR and LSS

Of these seven factors workstation, task-time and line type is concerned with assembly line balancing. The other four factors (process and equipment, activities, Operator and output) are concerned with gradual positive change.

2.1.4.1 One-piece-flow production

To go about line balancing for this feasibility study is to go towards a batch of one unit. Thus, different models are produced according to a daily plan. This is the vision of one-piece-flow production. Traditionally, different products are processed by the same equipment but with a WIP. In one-piece-flow production the WIP is eliminated since each product go into a separate process, see Figure 5. (Russell, 2013; Philip, 2013)

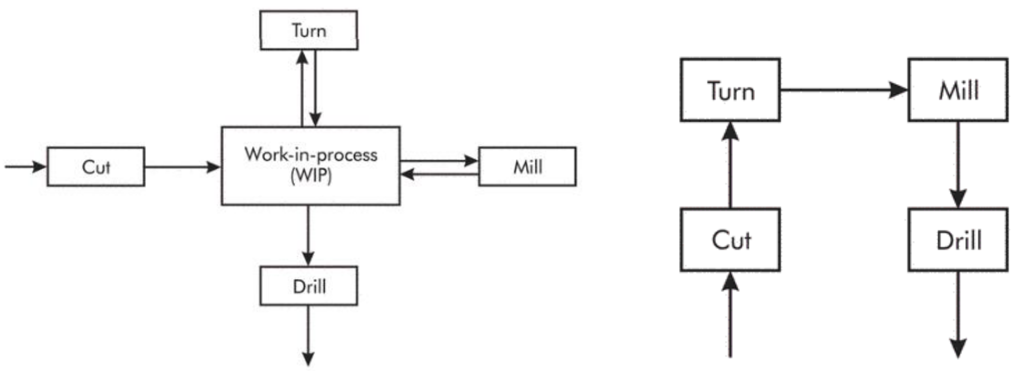

Figure 5. Traditional functional layout vs. one-piece-flow production (Philip, 2013: 354).

Furthermore, one-piece-flow production generates a completed task within a task time. This task in turn is balanced by another task being completed. Also, it deals with multiple parts of a product. When a part is assembled in one station, the work begins in next station. Thus, a pull system is generated, and lead time is diminished. Assembling parts based on customer orders synchronises demand with supply. It also synchronises the right demand with the right supply since the team can adapt to different parts being ordered from the assembly line. Note that competencies and skills of the Operator are requested to be more versatile. Which indicates s/he must assemble products with *higher* volumes, *low* variation in demand, *low* variety of the parts or product and with *low* visibility of the product which entails a multifaceted sense of quality.

There are more advantages of one-piece-flow production, also known as single-piece flow production. This includes the time from placing an order to handing over the product being decreased compared to batch size production. Instead of waiting for following batch, the process produces parts evenly by transforming resources constantly. All stations are operated simultaneously and there are several Operators managing the operations instead of a single Operator doing all the work. Each station amounts to a set of tasks in a logical and efficient sequence in relation to the previous and next station. However, when there are stops or deviations the whole assembly line stops to deal with the issue. Which lets the Operator take ownership of his or her work since misconduct affects the other team members' work. In addition, batch size production has more muda, mura and muri as described in Section 2.1.4 compared to one-piece-flow production (Russell, 2013; Daniel, 2007; John, 2014; Gornicki, 2014).

2.1.5 A system for operations management

Currently, there is not a detailed OMS. There is a competence based working strategy relying on Operators' accumulated experience and knowledge. This makes operations dependent on people rather than dependent on a standardised system and standardised practices.

A standard is therefore necessary for the execution of this strategy in a methodical way aligned with organisation strategy and business objectives according to Ortiz (2006) as well as Bergman and Klefsjö (2014, p. 45). A standard is derived from e.g. a handbook or regulations.

2.1.5.1 Desired operations management system--

The development of the desired OMS is based on data provided by the headquarters. These guidelines and directives are interpreted into an OMS. EPPC OMS is ABB Kabeldon's way of working with LSS to manage people, operations and quality. The vision at the department of Electrification is to implement a model for Operation Quality Excellence with the envisioned belief that quality brings value. The strategy is to go towards one-piece flow production and to make work conditions simpler by providing visualisation of instructions, equipments and practices for transparent assembly operations that are standardised. Once the processes are set for business management a structure for the organisation and its methods & equipments is formed. Accordingly, qualification of people and LSS within each production department exist. To make sure that *quality wins* which is the approach of the EPPC OMS.

QW is a state of quality which intends to go from a reactive approach of reworked quality through a preventive approach and finally to a predictive approach of planned quality. This strategy is encompassing department strategy. In this way, people, operations and quality are managed in detail and nothing is overlooked.

There are a set of goals that are a result of the Operation Quality Excellence model. These goals are aimed to be measurable and arguable. The organisation wants to have 500 PPM or lower for customer complaints. This factor is used to compare production efficiency as stated by Bebr et al. (2017). A project goal that is of interest and of relevance to this study is to define and implement a new model for quality and operational excellence. Consequently, institutionalising new work standards throughout the department and managing change by driving the quality approach.

Quality starts by beholding it at the production site and connecting it to certain methods and tools to generate a system for the management of quality. At each work stage of the EPPC system there are tools and methods to assure, check and control quality. The work stages are interconnected by these tools and methods creating a synergetic relationship between resources and operations. The decision to use these tools are based on motivational factors and advantages. These are listed here because it is necessary to understand each activity before it can be decided whether it should be used at the accessory assembly line or not. Prerequisites are set for each stage and its activities to ensure it is possible to undertake prior to implementation. However, these prerequisites are not of interest in this chapter since it is not necessary to delve into the OMS so deeply due to demarcations discussed in Section 1.4.

Q1: Quality Gates and Feedback Loops
Quality circles are practical, systematic troubleshooting and reporting on three different levels within the organisation.

Q1.1: Quality Gates
Quality Gates are control mechanisms to ensure that work/work activities are carried out correctly. They are used to control and plan quality in each step of the assembly line by using zero defects principle. Deviations and recurring problems are processed by communicating them between team members. To minimise costs of rework or repairs.

Q1.2: Andon
An Andon-resource is appointed to unburden production and to ensure the right production rate is withheld. Consequently, team members are held responsible of their actions and each production cell. When Andon oversees work and proactively supports team members with gradual positive change on the assembly line. He/she also decides how to schedule work in detail in collaboration with Material Handler and Operator(s).

Q1.3: Quality Feedback Loops
When using Quality Feedback Loops, follow-up of systematic troubleshooting is prompted daily. As a reaction to internal and/or external customer. Between departments, i.e. between blue-collar and white-collar team members, reoccurring problems and defects are communicated for positive gradual change. For the process and its production output. Knowledge is shared and documented to ensure the processes mature and become better.

Q1.4: Cross-functional Quality Feedback Loops
When using Cross-functional Quality Feedback Loops several departments are involved to ensure highest quality when defining a plan to recognise and solve root causes of occurring problems.

Q2: Operational Quality KPIs
Containing classification of defects with pareto-diagram, root cause analysis, 5Why and action plan to make sure changes are retained.

Q2.1: Standardised Operational Quality KPIs
This intervention is demanded due to lack of knowledge about the quality performance of respective cell. To rapidly respond at the correct place in production. It is to enable process steering and goal definition based on the accumulated KPIs.

Q3: Problem-solving
Visualisation of performance based on key performance indicators where First Pass Yield and deviations are measured.

Q3.1: Practical Problem Solving
The demand of this intervention is because issues are not categorised nor inspected leading to no priority list of deviations. The approach is reactive without measuring, root-cause analysis or justifiable answers. These eight steps are organised according to a cycle of planning, doing, checking and acting (PDCA).

Q4: Standardisation
Standardised modus operandi by defining ingoing work activities, structuring execution of work in a specific order, identifying how work is completed and ensuring the completion, defining time limit and production rate for each work activity.

Q4.1: Standard Operating Instructions
There is variation in the execution of activities possibly resulting in deviations and deficiencies. Therefore, there is a demand for standardisation of how to operate machines, communicate requirements on quality and equipments. It is needed to simplify the Operator's modus operandi independent of the person operating machines. The recognition of the root cause of an imperfection is easier to point out by analysing from a set standard. Standardised operating instructions (SOI) are step-by-step instructions, quality requirements, relevant equipments/parts/manoeuvring put in action in the assembly line. Important practices are visualised based on specific methods and explained explicitly.

Q4.2: Standard Routine Inspection Instructions
The demand is due to lack of objectivity when scrutinising errors. Different routine is done for the same reason when managing quality issues. Quality inspection experts order what to do thoroughly. An inspection is based on data to be gathered regarding specifications, processes and decision criteria. So quality inspector and customer share the same understanding of good and bad quality.

Q5: Qualification
Required competencies are established. Leaders are following through, develop and coach team members to sustain the right competence.

Q5.1: Qualification Matrix
The demand for a qualification matrix is due to the unrelated competencies of people embarking a new project. A trait of flexibility is demanded to proactively deal with unforeseen happenings. There is a process circling and shifting of staff between cells. Qualification matrix is solely focused on training towards goals and goal achievement excluding other competencies that are not functional.

Q6: Shop Floor Management
Shop floor management is standardised for team members to ensure that above (Q1-Q5) is upheld.

Q6.1: Meeting Structure
The reasons to activating this intervention are that information is being derived informally. The path of information is ambiguous. Problems arisen in production are not addressed fast enough by managers. By having a meeting structure production is consistent, communication is structured and focus in on results with a predetermined way of managing issues. Meetings are ordered to align with next level meetings when there is an issue to share. Actions are set to respond to changes. Existing subjects are continually fed backwards or forwards (Q1.3). The goals of this intervention are to ensure a fast response time to existing problems and continual reciprocity of information. In addition, information is not reiterated, insufficient or managed subjectively.

Q6.2 Audit and Process Confirmation
Because the organisation must be sure that the rights things are done in the right way which has been agreed upon. Changes result in new processes and instability. Clarified roles, activities and responsibilities are devoted to by Operators. Management is consistent enough for sustainable work practices and standards. When a degree of standard is achieved the goal is to keep it by using audits consistently and illuminating the status quo. The mental shared models are agreed upon in an organised manner. Activities are performed sustainably as a result of continual evaluations.

3 EMPIRICAL DATA

This chapter explains how all empirical data were gathered is explained and argued for. Both data deducted from company reports and discussions with white-collar employees and data from observations, surveys and interviews.

The department of Accessories is described to provide a background of the sources. As well as more in-depth exploration of the context in which the problem resides. The interviews, surveys and observations are thematised in chronological order.

3.1 Department of Accessories

The company has three envisioned values they want all employees to possess and work by. Namely, responsibility, determination and respect. Their Human Resource Manager described the organisation stating

> *"Kabeldon low voltage distribution systems by ABB are designed to deliver safety, ease and reliability for electrical distribution. Our customers typically include utilities, OEMs, panel builders and industrial companies." (ABB Kabeldon)*

The problem area was within the operations at the accessories' assembly line. Here lie four work centres divided into seven workstations. These workstations were operated independently by Operators who performed tasks according to a work plan. The assembly line system was consisting of an Operator, tools, machines, manual assembly lines and instructions. There was a warehouse from which parts were extracted. A "Supermarket" contained parts as well for easier and faster distribution of frequently used parts.

There was a data centre where computers were used to see scheduled work. It was also used for printing out labels and installation instructions. As well as reporting completed pallets, ready for shipment. At Accessories, toggles were assembled, and pre-assembly of cable distribution cabinets was done.

There was no specific OMS but there was a Co-ordinator with extensive experience at the department. Notice that he was not an Andon since this role had not been established. The production team worked in one shift, from 08:00 to 16:30. From Monday to Friday, with different Operators managing the process. One and a half team members worked in the first work centre at two workstations, one and a half in the second work centre at one workstation, two in the third work centre at two workstations and three in the fourth work centre at three workstations resulting in a team of eight individuals during an optimal shift. They worked consistently on assembling the disconnector Product A, in Figure 8, amongst other products but there was no documentation on defects. There was a scrap list provided to the Co-ordinator to note scrapped parts of Product A.

"The disconnector FD 3300 is designed for parallel use enabling the busbar system to be disconnected without stopping the current from the incoming cable passing through." (ABB Kabeldon)

Figure 8. Disconnector Product A (ABB Kabeldon).

The overall organisational strategy was to decrease deviations, defects and associated costs whilst increasing quality and performance. Simplifying operations and making processes transparent in the eyes of the whole team including all stakeholders.

3.2 Observations

Observations were conducted during meetings, breaks and daily conversations as well as at the operational setting such as the assembly line, warehouse, pre-assembly and neighbouring production. To get insight into organisational norms, practices and beliefs. Based on the definition of an observation as

> *"Observation is a method that relies on a researcher's ability to gather data through his or her senses." (O'Leary, 2017: 251)*

The study consisted of unstructured observations. I processed the world via senses in a mental model I had with an output of official observations. Besides from Operators, data was also collected from conversations with Production Development Specialist, Production Supervisor, Salesmen, Product Manager and Production Planner. These people, amongst the whole department, were informed about the ongoing study and a Data Privacy Policy was signed by the company and me as a researcher conducting a degree project. The ethical and safety aspects were thereby accounted for.

Furthermore, an observation list was created including all observations done during the initial phases of this study, throughout data collection and until analysis and results. Observations required a receptive approach from me. Observations required the ability of reflection to meet expectations on the situation and account for the presumptions I had when intending to observe. Respect of access, timing, cultural ignorance, comfort zones, recording/note taking, roles and objectivity also played a role in the outcome of an observation.

3.3 Interviews

Interviews which were unstructured consisted of non-random, hand-picked sampling comprising of experienced people of the operations (O'Leary, 2017: 239-249). The goal was to elicit previous experiences of the interviewees. Increasing the possibility of produced knowledge as a basis for one or several gradual positive changes. Interviews were held with seven team members from different departments at different stages of Lean Six Sigma implementation. The sample size was therefore seven. Two Andons and one project member at the assembly line of cable distribution cabinets. One Co-ordinator at the Accessories assembly line, one Andon at Fusegears and Switches and one experienced Operator in-between these two departments. One Andon at Surface Treatment.

Each interviewee was invited by receiving an Information Letter, see Appendix A. S/he was also required to admit consent by completing the Interview Consent, see Appendix B, prior to interview recording. The interview consisted of the subjects listed below. The full Interview Guide can be found in Appendix C.

1. Introduction
2. Organisation and responsibilities
3. Gradual positive change
4. One-piece-flow production
5. QW/LSS project

6. Termination with finalising questions

3.4 Surveys

People from all production departments were asked to participate. Team members from Cabinet Assembly, Fusegears and Switches, Accessories, Press, Barrel and Rack lines, Material Handling, Goods Reception, Powder Coating and Surface Treatment. Thus, the population was production team members working within ABB Kabeldon.

The survey was explanatory where the aim was to increase understanding on individual and organisational level. To provide a basis for decision-making on one or several gradual positive changes that could improve production. Focus was on cause and effect of changes. (O'Leary, 2017: 225-237)

The sample was those who accepted to participate and answer the questions. It was random, cluster sampling focusing on insiders giving information on their perceived reality at the production departments. Thus, a sample size of 21 people. There were open-ended questions, questions with options and mostly questions with a Likert Scale of 1-5 options in the respondent's perspective. Where 1 was strongly disagree, 2 was disagree, 3 was nor disagree or agree, 4 was agree and 5 was strongly agree. The data were collected using internal surveys, see Appendix D. Responses were manually inserted into an online software to produce results such as charts or graphs.

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The questions addressed following subjects:

- Distribution of respondents from each department.
- Examples of things that facilitate gradual positive change towards one-piece-flow production.
- General perception of gradual positive change at respective department.
- Desire to change.
- Differences between one-piece-flow production and batch production.
- Importance of learning as a part of change management.
- Faith in Quality Wins/Lean Six Sigma to improve respondents work situation.
- Lack of knowledge about Quality Wins/Lean Six Sigma.
- Quality Wins/Lean Six Sigma making work more practical.
- Importance of feedback from management.

The aim was to allow comparison on the matter of motivation in relation to change and learning. Dependent on how long a person had experienced LSS changes. To reach a greater population than interviews and supplement interviews with generalisable data from the whole production site.

3.5 Ethical considerations

When I conducted research, it was important to be conscientious throughout the study (O'Leary, 2017: 70). I exerted power but was doing so with the well-being of the participants in mind. The participants were treated according to their profession as Operators and blue-collar employees to make this research equitable. I was also honest about the happenings and the purpose of investigation.

Subsequently, besides aforementioned moral obligations there was a need for justification of right and wrong towards the study and its stakeholders. Following guidelines were taken into consideration to make the study acceptable by all stakeholders.

No harm came to participants, not physical harm nor psychological harm affecting the emotions and thoughts of an individual severely.

Informed consent was clearly defined and received by the participant. He/she understood how much of his or her time was consumed, what he/she would do, what risks that needed to be managed and what was included in the study and/or observations. The participant had some prerequisites to fulfil such as being knowledgeable and familiar with the subjects studied and independent by taking decisions on his or her own. He/she was volunteering to take part of the study and/or observations and could abort the mission whenever wanted. He/she was not beat around the bushes and no form of power was misused to force participation. He/she was not tempted to deviate from honest, moral and ethical correct behaviour when participating.

Confidentiality was a priority and considered when creating the interview guide, survey and observations. There was a choice of anonymity to ensure the participant's safety and right of sharing his or her opinions without any connections. Raw data was stored securely, restrictions to data were set by following rules of the company and the university. More data were shared when asked for and, if necessary, raw data were destroyed.

The literature review was based on articles and books which had been written by experienced researchers. The work of these authors had been published by publishing houses and/or in journals. All articles and books had induced data from practical and theoretical studies. Either done by themselves and/or deducted from other researchers' studies. It was therefore ethically correct by referencing and sourcing the theoretical data.

4 METHODOLOGY

The study was conducted by investigating the current situation at ABB Kabeldon, specifically Accessories. Current literature representing assembly line balancing problems in relation to one-piece-flow production and LSS was also reviewed. Thereby, approaching data collection through triangulation. Using interviews, surveys, observations as well as company data consisting of reports and inquiries.

The most suitable way to approach this research and gather data was by mixing quantitative and qualitative methodology. Qualitatively, it was of importance to focus on observations of the assembly line by using experiences and opinions of Operators. Also, by using observations of the production process in order to understand the problem empirically.

Quantitatively. it was of importance to rely on data and models that were presented in numbers which could be interpreted. Technical data aided to answer research questions. Methods of technical data collection were according to LSS. It was used to understand what the real circumstances and constraints of the study were. (O'Leary, 2017: 299)

To make best use of the changes it was significant to address the issue of learning. The department's strategy was to plan the changes, which implied learning the behaviour of Operators and the rules they worked by. Even though there was fruit of labour when treating knowledge as a commodity full of meaning it had to be effectively dealt with due to e.g. politics, logistics or ideologies. (Hayes, 2007: 71)

Consequently, the model in Figure 9 was created by researcher. It was utilised to make sense of theory and align it with the company's case.

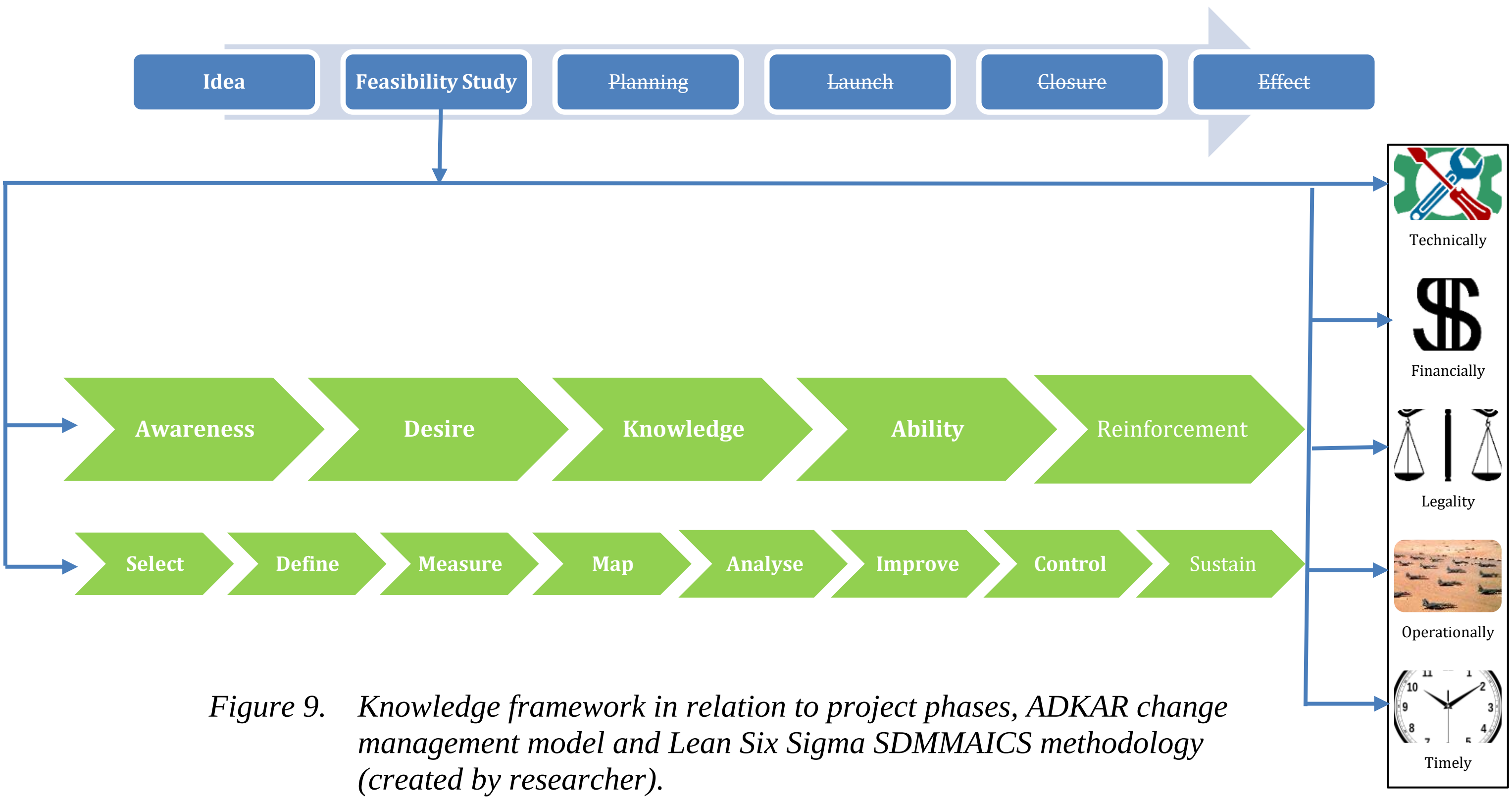


Figure 9. Knowledge framework in relation to project phases, ADKAR change management model and Lean Six Sigma SDMMAICS methodology (created by researcher).

4.1 SDMMAICS and ADKAR

Altogether, there was a methodological design which constituted a plan for how to conduct research relevant to the study. The method of data collection came out of prevalent techniques. This resulted in empirical data and theoretical data. Theoretical data contained knowledge from a literature review presented in Chapter 2. Empirical data contained knowledge from interviews, surveys and observations at the company explained in Chapter 3 and presented in Chapter 5.

The DMAIC method was used to define the problem (Define), quantify the problem (Measure), recognise the cause of the problem (Analyse), implement and verify the gradual positive change(s) (Improve) and maintain the gradual positive change(s) (Control). Phases to execute were added such as the selection of projects (Select) prior to the Define phase. After the Measure phase there was a phase to map the process (Map). In order to ensure changes had been accepted and the new way of producing products had been aligned with the business a third phase was added (Sustain) after the Control phase. This SDMMAICS method was an extension of the DMAIC method and was according to Sreedharan & Sunder (2018) an improvement and cross-functional with project management. By which the project was better executed, and more sustainable, since focus was also on issues in terms of the iron triangle (time, quality, cost and scope) than only on machines and equipments.

However, it was not enough with a statistical model based on organisational and productive facts to capture the essence of LSS. As described in Section 2.1.2 it was critical to manage people for a successful change project. Therefore, ADKAR model for change was paired with the SDMMAICS model to facilitate a path for human change within the feasibility study. Existing gaps were satisfied, and the model was complete from a strategic level.

Together they constituted a plausible methodology to manage the change process within the department (Singh and Rathi, 2019; Galli, 2018; Galli, 2018; Boca, 2013; Sunder, 2016; Tenera and Pinto, 2014; Sreedharan and Sunder, 2018; Wang and Liu, 2019; Drohomeretski et al., 2014; Patil, 2015):

1. Awareness (ADKAR) was built when selecting and defining the project (SDMMAICS). By choosing tools to understand the necessary change and its constraints on the project.
2. People were desired (ADKAR) to embrace the change when measuring the inputs, transformation and outputs. The process was mapped to understand how the measurements could be affected so the direction of change was focused. (SDMMAICS)
3. Knowledge (ADKAR) preceded a credible take-off towards the destination. All stakeholders, especially those in management, were required to responsibly seek out information to identify the context in which change resided. And/or invite communication of the technical, operational, financial, legality and time-related aspects to learn about the changes. Only then could those facts be analysed (SDMMAICS).
4. Next, the ability (ADKAR) to perform these tasks were based on measurements and an analysis to successfully go towards one-piece-flow production deploying positive gradual change (SDMMAICS).

5. Finally, the consequences of the change process in structures, procedures and practices can be reinforced (ADKAR) by control mechanism. Using standard operating procedures and training manuals (SDMMAICS).

4.1.1 Select

In line with ADKAR, stakeholders became aware of the assembly of Product A at the department. The necessity of change and the amplitude of it was made aware. When selecting the project in relation to time, quality, cost and scope. In addition, when reaching out to stakeholders to gather data they were also made aware of what the project entailed and how they could contribute. Negotiations were made and an agreement on the chosen project was made. As a result, there was a baseline to fall back on when the project got complicated.

To determine if the project was suitable relevant parameters were assessed. In other words, it was related to the company's vision and philosophy. Related to if LSS was suitable for the actual process. If the ROI was favourable. If the project was aligned with overall strategy of the department (Sreedharan and Sunder, 2018).

The starting point of this phase and the whole SDMMAICS was a mind map. Which was according to Russell (2014: 340) and George (2005: 254) a method to manage thoughts and ideas at an early stage of this feasibility study. It was generated by previous experiences, previously accumulated knowledge, intuition, curiosity and creativity.

Consequently, a force-field analysis was created. It helped to unify the stakeholders. In this study, each Operator received an opportunity to share their knowledge in interviews and surveys. With a degree of subjectivity vs. objectivity, what was believed as driving forces and restraining forces. Russell and Grace (2015) continued by emphasizing that this tool enabled objectivity and focus on the problem rather than using communication for personal gain. The forces were separated so driving forces countered restraining forces. As a result, driving forces were strengthened whilst restraining forces were diminished.

4.1.2 Define

When the team was sure of which project to pursue, the problem was defined. It was necessary to talk to people with different but relevant roles within the organisation to build awareness in line with ADKAR. To have a baseline for project change constraints after choosing the most appropriate project. This process of project selection inevitably led to change. Change could be divided into four sorts, see Table 1. These changes provided an understanding of the current situation and the future state of change management within the department. To get to the future state, the department needed to undertake a process of change.

	Incremental	Transformational
Proactive	Tuning	Re-orientation
Reactive	Adaptation	Re-creation

Table 1. Typology of organisational change (Hayes, 2007: 15).

Tre transformation process was defined in terms of input, transformation and output. Followed by the operational dimensions. According to Ghosh and Gagnon (1989) as well as Sivasankaran and Shahabudeen (2014) there were eight types of an assembly line balancing problem. Therefore, the problem was also defined from these perspectives.

The stakeholder analysis was a method of communication. Since s/he could make or break the project it was important to manage the psychological needs. Only then could an appropriate strategy of either tell and sell or identifying and replying be made. The model for stakeholder management illustrated in Figure 10 was used.

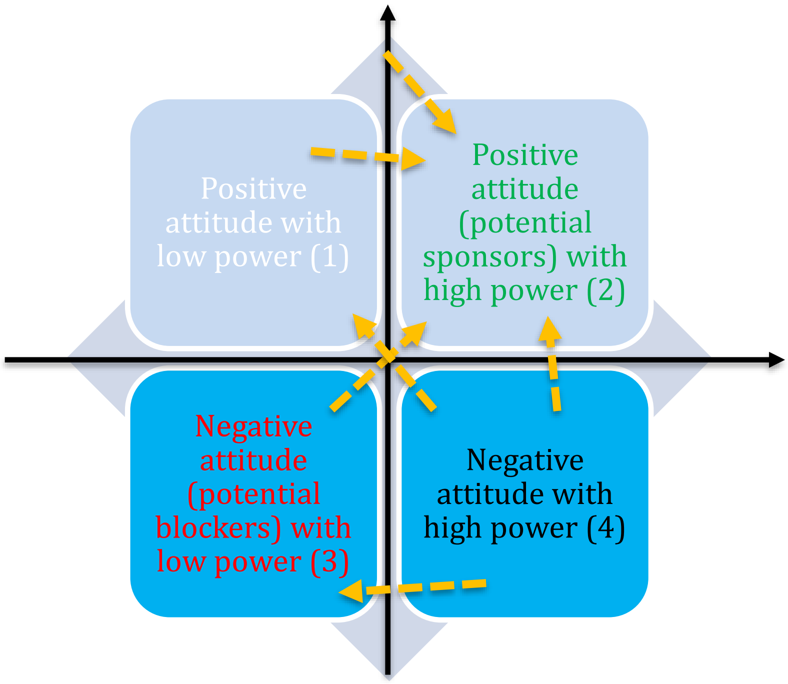


Figure 10. Stakeholder grid with stakeholder influence in x-axis and stakeholder interest in y-axis (Hayes, 2007: 210).

The strategy was to manage stakeholders from grid (4) to grid (2). To provide the person with information on how they could benefit from the project and make them supportive by letting him or her influence the project in a positive direction. It was to steer those in grid (1) to grid (2). By enabling them to gain a position of power or arrangements where they could use their attitude to positively affect those who were less inclined to change. Those who were in grid (4) had to be distracted from decision-making by ending up in grid (3) with less power or possibility to influence the project negatively. Suggestively, through bargaining. In a collaborative effort, individuals in grid (1), (3) and (4) should be aimed to end up in or get closer to grid (2) to back up the changes. Finally, potential sponsors needed continually be sought out when opportunity of engaging them arose. S/he could be found with idle power to aid the project or with an attitude that could join and unite key individuals in the project.

To complete the definition and provide a comprehensive description of the upcoming change a SWOT-analysis of Product A was made. To understand what technical strengths and weaknesses it had along with operational threats and opportunities.

4.1.3 Measure

People were desired, according to ADKAR, to embrace the change when measuring the inputs, transformation process and outputs. Involving the relationship of tasks and operations with the Operator. Thus, the Operator was involved when measuring the current performance based on his or her work. The four principles regarding flow, takt, pull and zero defects were measured.

The pull principle considered Mura which lead to overproduction of Product A. This was measured by providing numbers on how much that was produced and how it affected production. It was based on observations and company data. The assembly line balancing was conducted by producing a precedence diagram based on data gathered from observations. The aim was to provide data for the waste analysis.

The flow principle considered waste because of muda. Which was waiting in-between operations or during an operation. Also, the operations were possibly faulty or misused resulting in deficiencies on Product A. These practices affected flow of material negatively. This was measured by creating a spaghetti diagram. Where the Operator’s movements were visualised. (Georg, 2005: 42)

Takt was considered by measuring the takt time of the product. Waste due to incompatibility with CT was recognised. The takt was measured in relation to the customer demand. It was based on Equation 1 (George, 2005: 54; Cannas et al., 2018).

$$Takt\ time = \frac{Effective\ time\ available\ per\ shift}{Customer\ demand\ on\ production} \quad (1)$$

The zero defects principle concerned waste due to muda which was defects on Product A. Defects were measured based on the number of products that were not accepted by the customer. Which were returned to ABB Kabeldon. These customer complaints were measured to provide basis for improvements which could eliminate muda. Equation 2 was calculated to understand parts per million that were defective.

$$PPM = \frac{Total\ number\ of\ defective\ units\ found\ in\ a\ sample}{Sample\ size} \times 1{,}000{,}000 \quad (2)$$

Furthermore, Sivasankaran and Shahabudeen (2014), Georg (2005: 199) and Cannas et al. (2018) described CT as presented in Equation 3.

$$CT = \frac{Effective\ time\ available\ per\ shift}{Production\ volume\ per\ shift} \quad (3)$$

In order to know how efficient an assembly line is Equation 4 was calculated (Sivasankaran and Shahabudeen, 2014). The balancing line ratio, in Equation 5, was used to understand the relationship between one workstation and the whole assembly line. Required Operators were calculated to determine how many Operators were necessary for production to meet customer demand, see Equation 6. Which was used during analysis to compare future and previous state of the assembly line dependent on the number of workstations, task times and the workstations' CT. Lam et al. (2016)

$$Balancing\ efficiency = \frac{Sum\ of\ all\ task\ times}{Number\ of\ workstations \times Cycle\ time} \quad (4)$$

$$Balancing\ line\ ratio = \frac{Sum\ of\ all\ task\ times}{Total\ relative\ cycle\ time} \quad (5)$$

$$Number\ of\ required\ Operators = \frac{Sum\ of\ all\ cycle\ times}{Takt\ time} \quad (6)$$

4.1.4 Map

People were desired (ADKAR) to embrace the change when the process was mapped to understand how the measurements could be affected so the direction of change was focused. By visualising the process and using factual data to describe it the problem could be understood holistically. Product A could be understood on the operational level to grasp the problem. The process could also be altered by using the documents prior to changing the assembly line. To be sure of how future operations should be interconnected. It was also a tool for communication to satisfy stakeholders' interest in the project.

A SIPOC analysis was made. It consisted of a definition of the supplier that generated an input for the process which in turn produced an output that was transported to the customer. In this way, the boundaries and scope of the project were clarified (George, 2005: 38-39).

By going the Gemba and walking through the process in production a process map was created. Thus, the real situation was captured by observing how an Operator proceeded assembling Product A from start to finish.

4.1.5 Analyse

Consistent with ADKAR and SDMMAICS, the ability to perform these tasks were based on measurements and analyses to successfully go towards one-piece-flow production by deploying positive gradual change. Once the process was measured and mapped could it be analysed to provide knowledge for possible improvements. As a basis for comparison balancing line ratio, line balancing efficiency and number of required Operators were used in several analyses. The analysis was divided into analyses of root causes, attitude towards LSS project, wastes, assembly line balancing and the Q6 model.

Why-why analysis was *"a basic technique used to push your thinking about a potential cause down to the root level"* according to George (2005: 145). Generally, it was asked to solve a practical problem. This supported the ADKAR model in terms of analysing the ability of a team member to understand why LSS was necessary. Also, it was to analyse qualitatively which other aspects that should or may be managed other than the technical aspect. The answer intersected with financial-, legality-, operational- and/or time aspects.

In the waste analysis, data from measuring the flow principle by using a spaghetti diagram was included. Data from measuring the pull principle by using a precedence diagram was also included. Based on the measurements of the pull principle activities could be determined as value-adding, business non-value-adding or non-value-adding. Georg (2005: 49-51) continued by claiming the goal of this analysis was to find unknown costs excluding value for the customer. It was also to simplify the process, diminish CT and more effectively produce products by using resources more efficiently.

Assembly line balancing concerned the technical, financial and operational aspects of the project. All executed activities were leading to an unbalanced assembly line with batches. Cannas et al. (2018) and George (2005: 234) described this analysis to minimise time consumption, WIP and work activities at each workstation. To make the process balanced in relation to these parameters so as the CT does not exceed, fall short of the takt time or differ too much from workstation to workstation. The precedence diagram and SIPOC analysis was a basis for autonomous line balancing without disrupting production. Work distribution was analysed so Operators could learn several workstations for broader qualifications. Production of batches were aimed at a batch of one unit. Waste of movements needed to be minimised. Standardisation of operations and simplification of decision-making were analysed. Line balancing also pertained to affordable equipment that focused on function over design.

The Q6 model concerned the legality aspect of the feasibility. All parts of the model were evaluated in relation to empirical and theoretical data. It was done to narrow down focus on appropriate activities which could be implemented. Correlated to learning, gradual positive change and quality management within operations.

4.1.6 Improve

As in Analyse the ability to execute changes was under scrutiny (ADKAR). The purpose of this stage was according to George (2005: 14-16) to learn from suggested gradual positive changes. Leading to a pilot of a solution and validation of it so as it was an actual improvement. As an LSS project, measurements, mapping and analysis were used to provide suggestions for problem-solving.

Internal benchmarking with other departments was done. Because similar problems were found in other department(s) where a solution was already in place. Thus, saving resources which could be used elsewhere (Slack et al., 2016: 562). Specifically, practice benchmarking was performed to learn from the way things were done at Cabinet Assembly as well as Fusegears and Switches. Within these departments LSS projects had previously been implemented successfully.

Brainstorming was a method to base gradual positive changes on root causes of the problem. To use the findings in previous stages. The attitude towards an LSS project, identified wastes and the assembly line balancing was processed to generate ideas. Ideas were proactively sought out by experimenting with the assembly line in collaboration with Operators.

Georg (2005: 253, 264) explained that the impact-effect matrix was used to prioritise suggestions for gradual positive change. In the top-left corner were gradual positive change that were quick wins. They contributed most to the success of a project and were prioritised first. The second type of gradual positive change to focus on were major projects that were in the top-right corner. They were long-term changes that required a run-through of the complete project life cycle. The first bottom-left corner was categorised as fill-ins. Gradual positive change did not require much effort or time. Therefore, fill-ins were deprioritised to third place. Least concerned were thankless tasks, in the bottom-right corner. They contributed least to the process and were managed without direct implementation. Also, to realise the suggestions a cost-benefit analysis, using Equation 7, was made.

$$Percental\ savings = \frac{Saved\ costs}{Total\ costs} \quad (7)$$

4.1.7 Control

As in Improvement stage, the ability to perform new or modified tasks were explored (ADKAR). To make sure the improvements were done appropriately. That agreements between stakeholders, especially Operators, Production Development and Production Supervisor were kept. It was imperial to have control mechanisms that ensured the changes were consistent. Which made it possible to complete the feasibility study and hand it over to the Process Owner.

Documentations of the suggestions and recommendations on how to maintain the changes were made by providing a feasibility report to the company. Summarising the study and five aspects of the study to form a basis for a pilot project. Mainly, technology-, finances-, laws and rules-, operations- and time constraints. (Georg, 2005: 17-19; Tonnquist, 2016)

Tickle-Degnen (2013) as well as Roy and Mukherjee (2017) claimed that a feasibility study was created for the purpose of clarifying the need for a project. In addition, it was to investigate if the project was feasible, if and which advantages there was for the organisation and its environment. These aspects were fortified by the SDMMAICS model and ADKAR model.

4.1.8 Sustain

Finally, it was advocated for sustaining the changes to reap benefits over time (ADKAR). George (2005: 232-234) claimed there were two ways of ensuring mistakes were not made. Thus, maximising benefits. Either by preventing mistakes to occur in the process. Or by making the process mistake-proof by adding mechanism for controlling the process. Supporting the Operator to make up for the human factor.

Consequently, Sreedharan & Sunder (2018) claimed that two to three months of monitoring was necessary for sustainable change management after the improvements were made.

5 RESULTS AND ANALYSIS

5.1 Select

The selection process is defined by the project constraints which in this feasibility study are illustrated in Figure 11. Due to limitations on costs there is more flexibility of time consumption. Also, the scope is limited to one process at Accessories in which the product Product A is being produced. Product A was one of 238 active products 2018–2019.

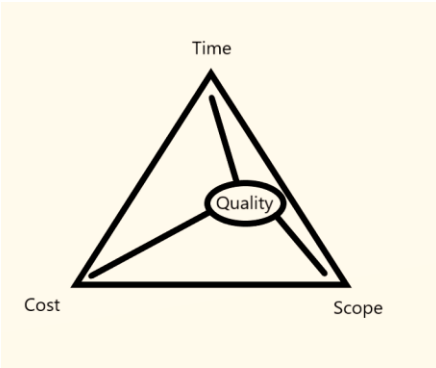


Figure 11. Project constraints (created by researcher).

The project is right by making sure it is relevant to the business vision and philosophy. The current vision of the whole organisation is to drive LSS in all departments. Thus, adopting a production system known as EPPC existing in other departments. By doing so, everybody is in the same boat and follow principles (pull, flow, takt, zero defects) aligned to business strategy independent of operations' function. The practices are intended to be based on these principles according to management at ABB Kabeldon. There is a shared understanding of what is happening on different levels of the organisation. From top management, to middle management and down to shop floor management and the team members at Accessories. Leading to both single-loop and double-loop collective learning. This in turn lays a solid foundation when norms are changed and/or understood. Knowledge is produced, gathered and transferred effectively from another department to Accessories and vice versa.

LSS can be used beneficially. Management can observe objectively that the project is possible to perform with positive outcome. The reasons for an LSS project are clear and concise and entail what formal steps are to be taken in order to overcome the challenges. As a result of a feasibility study prior to any realisation. There are definitions and measurements, the process is mapped, and the gradual positive changes are based on analysis. Control actions are determined to ensure gradual positive changes are followed through.

The ROI is favourable. When the actual project is implemented to manage change preceding accessory line improvement according to the new OMS. Financial information is a prerequisite for a solutions survival and to be taken seriously by upper management.

The project is aligned with overall strategy and the strategy of Accessories in particular. The other departments follow EPPC OMS and the LSS approach. The project is articulated step by step as this is done according to SDMMAICS and ADKAR. The chosen product Product A to study is used as an entry point to familiarise Accessories with EPPC and LSS. (Sreedharan and Sunder, 2018)

5.1.1 Mind map

Simply sitting down and freely discussing what the project could contain resulted in the mind map seen in Figure 12. It helped to visualise the problem area with a specific objective in mind. In collaboration with the R&D Manager and Production Development Specialist at ABB Kabeldon.

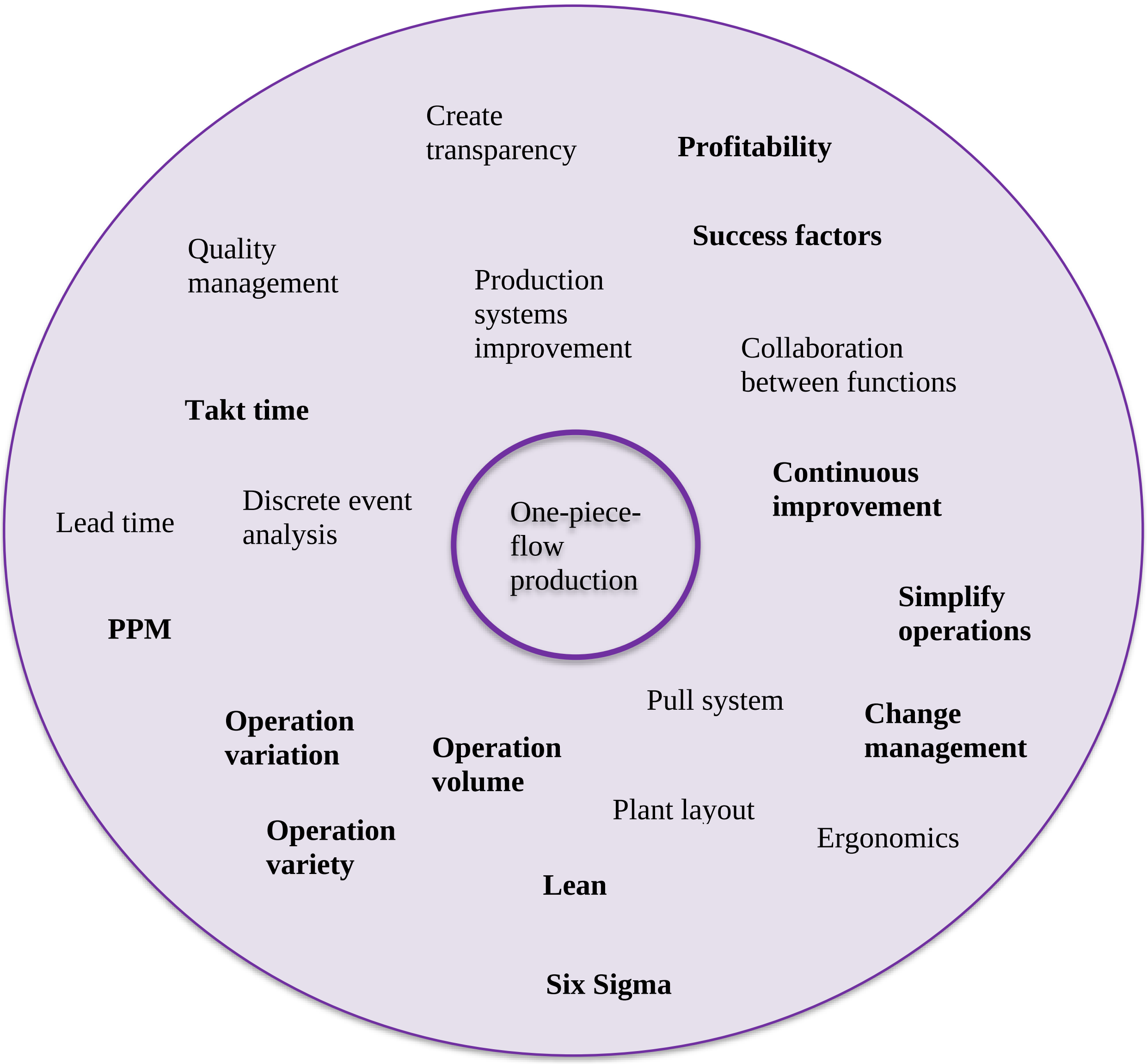


Figure 12. Mind map (created by researcher).

5.1.2 Force-field analysis

Combined with the data from interviews, observations and survey responses are the forces illustrated in Figure 13. They are related to five aspects of the feasibility study.

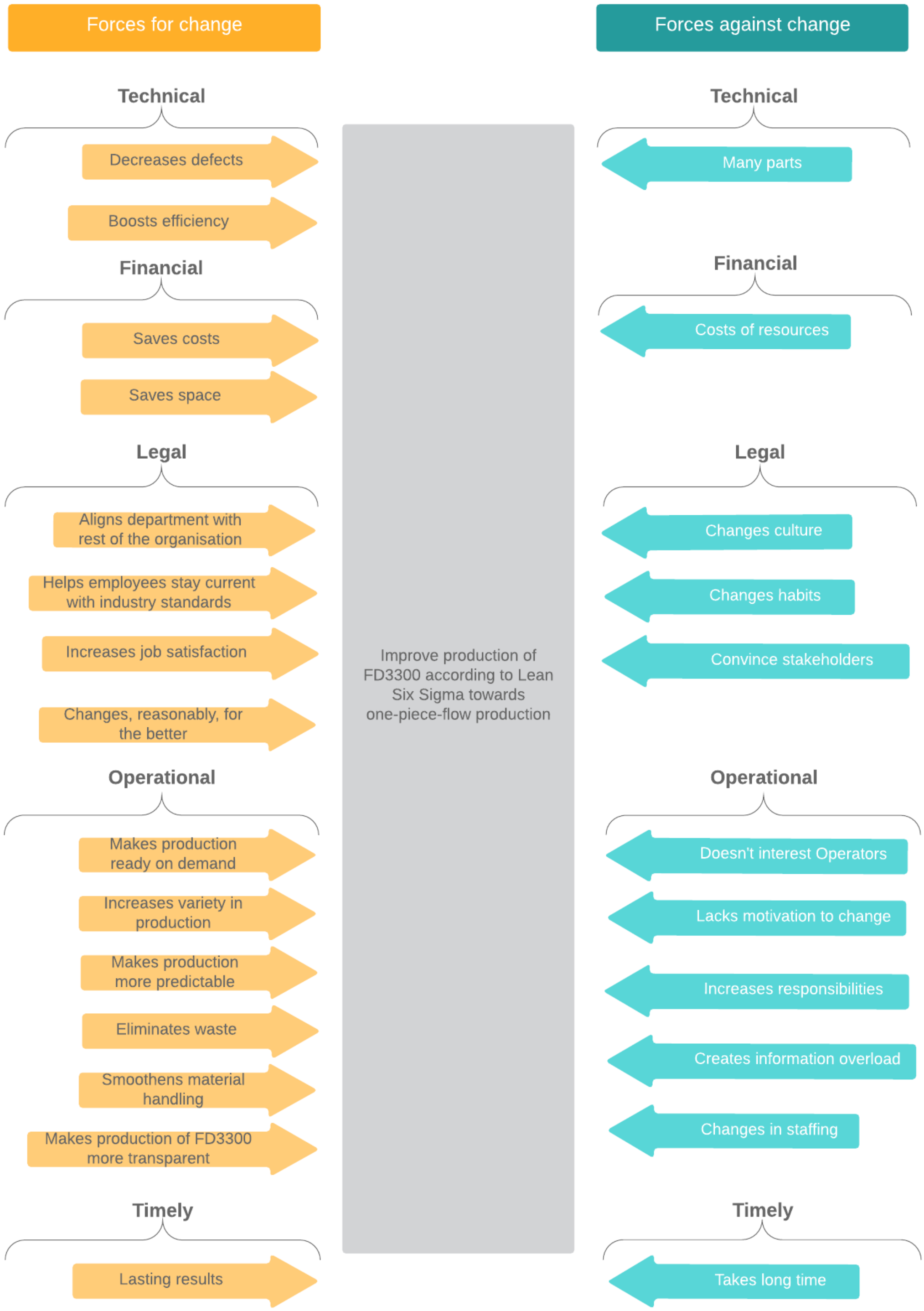


Figure 13. Internal organisational forces in relation to aims and objectives (created by researcher).

These forces are calculated to give an idea of which side of change that will prevail. The calculations are given based on observations and analysis of interviewees' responses. The number of forces is suggestive in nature to clarify how many forces there are. With equilibrium there will be no change.

(Hayes, 2007: 142-145) Besides the stated forces there are other driving forces. These were not shared by enough people to be considered as significant. On the other hand, they are relevant to be acknowledged. I.e. new challenges, making work fun. The responsibility of doing the work that is agreed upon with the organisation. Interest in the work and motivation to do it. Gradually changing for the better with continuous development. Having a raised salary.

In total there are 15 driving forces and 11 restraining forces. Excluding the five driving forces that are given by a minority of team members. Which indicates that there are more driving forces than restraining forces. Hence, the project can move forward towards objectives.

5.2 Define

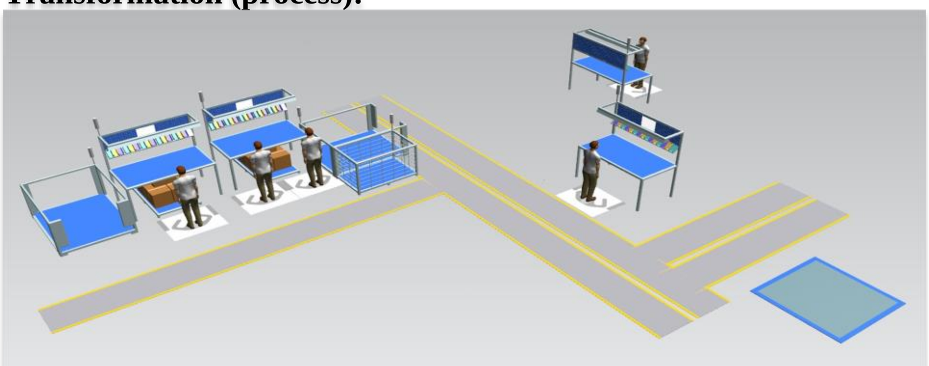
5.2.1 Problem statement

The problem, as described in Section 1.5, is a lack of standardisation to simplify interaction with the environment of the work centre. The product Product A is created at a work centre without assembly line balancing and by one single Operator. This may not be the best option. There is not enough transparency making it harder for all stakeholders to perform single-loop and double-loop collective learning. As the Research and Development Manager explains. To improve, adapt and overcome the challenges. The current change management is strategically emergent with the result of taking out fires instead of proactively engaging with quality issues based on accumulated data. Including the way equipments are managed, workstation structured, parts placed, and Operator stationed according to Figure 14.

Input of transformable resources:
Material: 29 articles (57 parts).
Information: Standardised operating instructions, work schedule.

Input of transforming resources:
Operators, equipment, workstations, pallets.

Transformation (process):



Output:
Finished product including a loose handle to be mounted post-delivery

Installation instruction

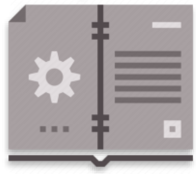


Figure 14. Input, Transformation and Output (based on observations and ABB Kabeldon's data).

The key resource in this study is the people who transform the process. According to interviewees an Operator is an individual who assembles products. Maintains work centre and one or more workstations as well as communicates improvements. S/he is subordinate to a Co-ordinator. He participates in production and follows up on deviations. He also alleviates pressure of an Operator by providing material and guidelines of work to do. Like an Andon but not as established and formally accepted.

Consequently, the process has characteristics. The operational dimensions in Figure 15 are compared to the other 238 products produced at the department based on observations and company data.

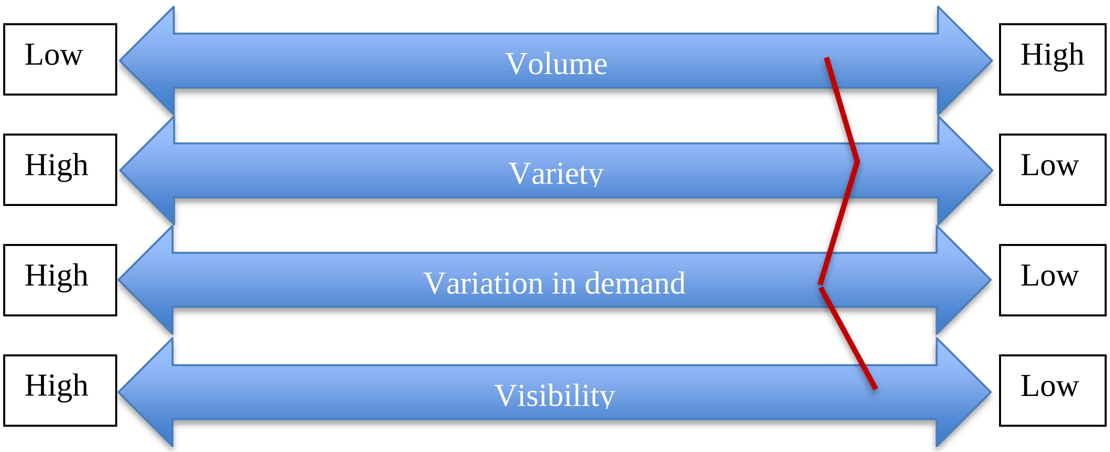


Figure 15. Operational dimensions (created by researcher).

Consequently, the costs of Product A are reduced since there are high volume, low variety, low variation in demand and low visibility. It is low visibility due to the product being inside a cabinet and only seen and/or touched when there is a need to disconnect the power grid which is not that often. Based on participatory observations made with the Operators at the accessory assembly line. The product is sold online with no customer contact. The quantity of produced Product A is high which is an average of 384 units/month during 2018 and 2019 compared to the average production of 125 units/month of other products. That is, three times the average amount of units produced during an average month. Variation in demand is low since around 300-400 Product A was produced during 2018 on a monthly basis. With the exception for July during vacation time when only 30 units were made during 2018 but 300 were made during 2019.

	Incremental	Transformational
Proactive	Tuning	**Re-orientation (2)**
Reactive	**Adaptation (1)**	Re-creation

Table 2. Typology of current organisational change (1) and future organisational change (2) (created by researcher).

As specified below, re-orientation is the proactive approach ordered by upper management to the production team. It is desired to effectively adapt to change and anticipate future change, as categorised in Table 2. This will lead to a new definition of the departments change management. However, current production will not be stopped but gradually change according to the new way of doing things (Hayes, 2007: 17)

Technically, the assembly line problem is deterministic by being based on the input and its parameters. More precisely the problem is a single-model, deterministic, straight-type (SMDS) problem since it is a straight line (Sivasankaran and Shahabudeen, 2014; Ghosh and Gagnon, 1989). Having one model produced at the assembly line. Which is based on input and mostly produced in a straight line. Except for the preparations as illustrated in the cover page. It is a simple assembly line balancing type 2 problem (SALB-2) based on the description of Koltai et al. (2014). Which needs to be managed to optimise production for the satisfaction of the customer's and organisation's needs.

5.2.2 Stakeholder analysis

Stakeholders are affected along with their environment and their respective organisational function. The stakeholders in Accessories and related departments that have a stake in the project are listed below. The list is based on interviewees' response to the question: *"Do You know how the organisation is structured at Your department? If yes, can You describe it?*". They are categorised in Figure 16.

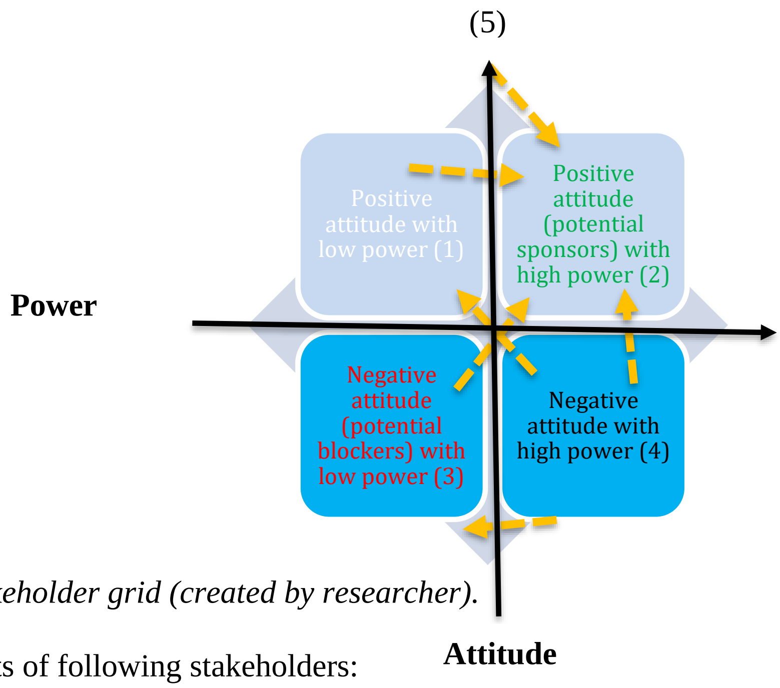


Figure 16. Stakeholder grid (created by researcher).

The grid consists of following stakeholders:

(1) Operator, Production Development Specialist, R&D Manager, Production Planner, Co-ordinator, Purchaser, Supply Manager, Maintenance Technician, Safety Representative.
(2) Production Supervisor, Quality Manager.
(3) Operator, Truck Operator, (Material Handler).
(4) –
(5) Project Sponsors: Global Manager, Human Resource Manager.

People in grid (1) may need participation and involvement to increase in power. Thus, having a strong balance of power between all stakeholders. For motivated responsibility and determination in the changes.

People in grid (2) are necessary to negotiate and come to agreement with. They can invite or invest in others so their attitude and reasons of high power can be understood and respected.

People in grid (3) are the ones that are mostly affected by the changes. They are educated and persuaded to become aware of the changes. To believe in the changes the project also necessitates facilitation and support by other team members. Since management does not have enough resources to provide additional Operators and Truck Operators.

People in grid (4) have a leading position with formal and, more importantly, informal power over work practices. Currently, this grid is non-existing since no stakeholder fits the description. However, such a stakeholder is bound by the norms and the takt set to guarantee productivity. S/he benefits from education and persuasion to become a sponsor of the changes and get the other team members on board.

The Project Sponsors are constructively managed to become promoters of change to get to a better state of performance. Also, to enforce the project with their network by increasing the attention that is paid to the project. However, both Global Manager and Human Resource Manager is only educated about the project to understand what the department is going through in terms of changes.

5.2.3 SWOT analysis

Product Product A has after discussions with several stakeholders from different functions within the organisation been chosen as an appropriate product to exemplify. Product management, production development, sales, operations and construction were taken into consideration. Combining information stated by respective manager or white-collar employee results in the SWOT-analysis in Table 3.

Strengths	**Weaknesses**
Fast disconnection of cable with busbar system Satisfied customer Can be stored to have multiple of Few remarks from customer Maintenance free	Low quality on housing Plastic material is not standardised Screws are too long to detach housing Different volume every year Unstructured work Unnecessary movements No stability in production output
Opportunities New market segments New export countries Improvement on plastic housing Predictable and stable production	**Threats** Different amount desired annually Possible to reach into the disconnector which is dangerous

Table 3. SWOT factors (constructed by researcher based on observations and discussions with white-collar employees).

Product A is sold by wholesalers on their websites, according to the sales department at ABB Kabeldon. Historically, it was advertised on fairs and through active marketing which is not the case today. The customers know about the product and it is an accepted product on the market with little effort on sales. The production is depended on sales in relation to volume. The amount differs from year to year depending on new buildings' and electrical companies' demand.

5.3 Measure

5.3.1 Pull principle

5.3.1.1 Precedence Diagram

Included are all tasks connected to the standardised operating instructions. Including the preassembly, Table 4 describes the work procedure to produce one Product A. The product is produced in batches. Each batch consists of 30 units which is produced based on the demand of the customer on a weekly basis. The duration is the average of 15 consecutive times a task is performed generating a half batch. The tasks are described to understand what is done to the parts. Tasks are clustered depending on the immediate predecessor and the relationship it has with equipment used at the workstation where the operation is carried out. The clusters can be seen in the precedence diagram below as an operation. Steps have been calculated to understand where movement is relevant to analyse. Finally, the tasks' interdependencies are illustrated in a diagram in Figure 17.

Task	Immediate predecessor	Task	Duration (s)	Operation	Number of steps
A	-	Screw together three yokes and three contact screws, separately in a fixture.	42	Operation 1 (Prepare operations)	1
B	-	Collect one connecting part of each type totalling to three connecting parts, three pressure pieces, one connecting rail and three insulating plates.	15		1
C	A, B	Start riveting machine and rivet each connecting part with a screwed yoke whilst riveting pressure piece to the riveted yoke in a sequence. Attach insulating plate.	48		48
D	C	Put only one of the three connecting parts in a second fixture to screw a rail with two screws onto it. Place insulation plate on it.	32		2
E	C, D	Grease all three connectors. Place connectors in bins.	25		2
F	-	Prepare and count three attachment knives delivered by Truck Operator.	5		2
G	-	Prepare three touch protectors and count them. Prepare one handle and count it.	4		2
H	A	Preassemble plug in a third fixture.	48		2
I	E	Collect connectors and prepare them.	5		2
J	-	Place a flawless socket on the	35	Operation 2 (Rivet socket)	4

		workbench. Place six rivets in the socket.			
K	J, H	Place socket in the fourth fixture. Turn socket and fixture. Put socket on riveting machine. Place three preassembled plugs in the socket. Start riveting machine. Connect fixture to the spikes in the riveting machine and perform riveting by using a pedal six times.	60		0
L	K	Place riveted socket onto work area and place three contact bridges into the fifth fixture.	14	Operation 3 (Assemble disconnector)	2
M	L	Place socket on the contact bridges and screw three screws in each hole.	16		0
N	I, M	Assemble first connector by attaching a retaining plate and screwing it onto the socket.	18		0
O	I, M	Assemble second connector by attaching a retaining plate and screwing it onto the socket.	23		0
P	I, M	Assemble third connector by attaching a retaining plate and screwing it onto the socket.	33		0
Q	M	Attach a label on the socket.	1		0
R	N, O, P, Q	Place the socket into a sixth fixture and grease holes for the attachment knives.	23		4
S	R	Refill grease: happens every 10th	9 (90/10)		6 (55/10)

		disconnector (90 holes) is assembled.			
T	G, R	Place a handle onto the fixture.	5	Operation 4 (Complete disconnector)	0
U	T	Push a housing on the socket and fasten with two screws.	26		2
V	F, U	Push inwards three attachment knives until resistance.	12		0
W	G, U	Turn the disconnector and push three touch protectors on top of it.	29		0
X	V, W	Place the assembled disconnector in a pallet until it is fifteen. Report the batch and replace pallet when it is full.	45		5

Table 4. Task description (created by researcher).

Total task time: 573 s (9 minutes 33 s) to make one unit. Which equals to 6,28 units/hour

Total number of steps: 39 steps

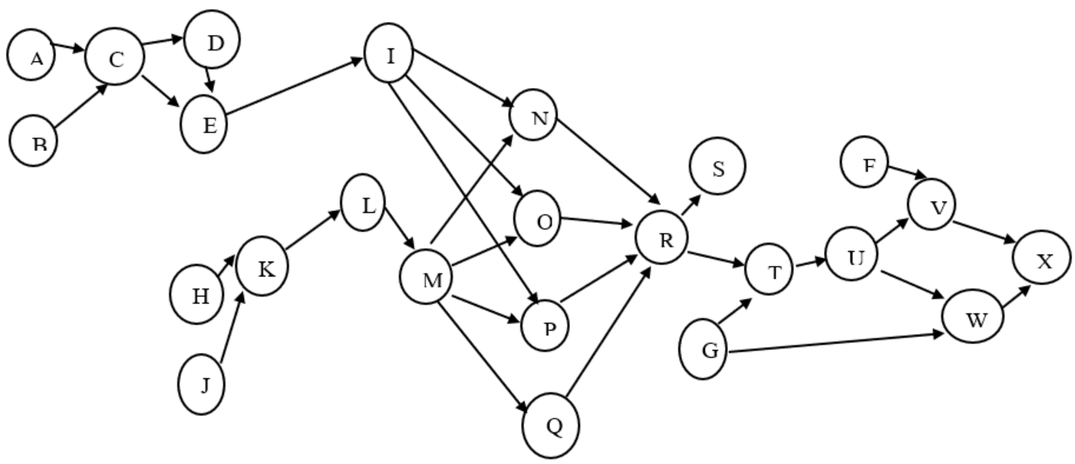


Figure 17. Precedence diagram (created by researcher).

5.3.2 Flow principle

5.3.2.1 Spaghetti diagram

There are four workbenches, but these constitute five workstations where the four operations are performed by one Operator. The 39 steps included in the precedence diagram stem from the spaghetti diagram in Figure 18. The extra movement under the socket pallet visualises a movement outside the frame. The Operator walks to another work centre within the production site which is outside Accessories. To refill grease for the attachment knives and bring the refilled equipment back to his or her workstation.

The movement of the Truck Operator is excluded even though it affects the performance of operations. If the Truck Operator does not provide materials the Operator must walk to the warehouse and get certain parts. There is an effect of this transaction which will be further demonstrated when the process is mapped. However, since this effect does not occur on a regular basis and is usually non-existing it is reasonable to overlook these movements. Movements in-between workstations are also overlooked since they are calculated to 0-2 steps.

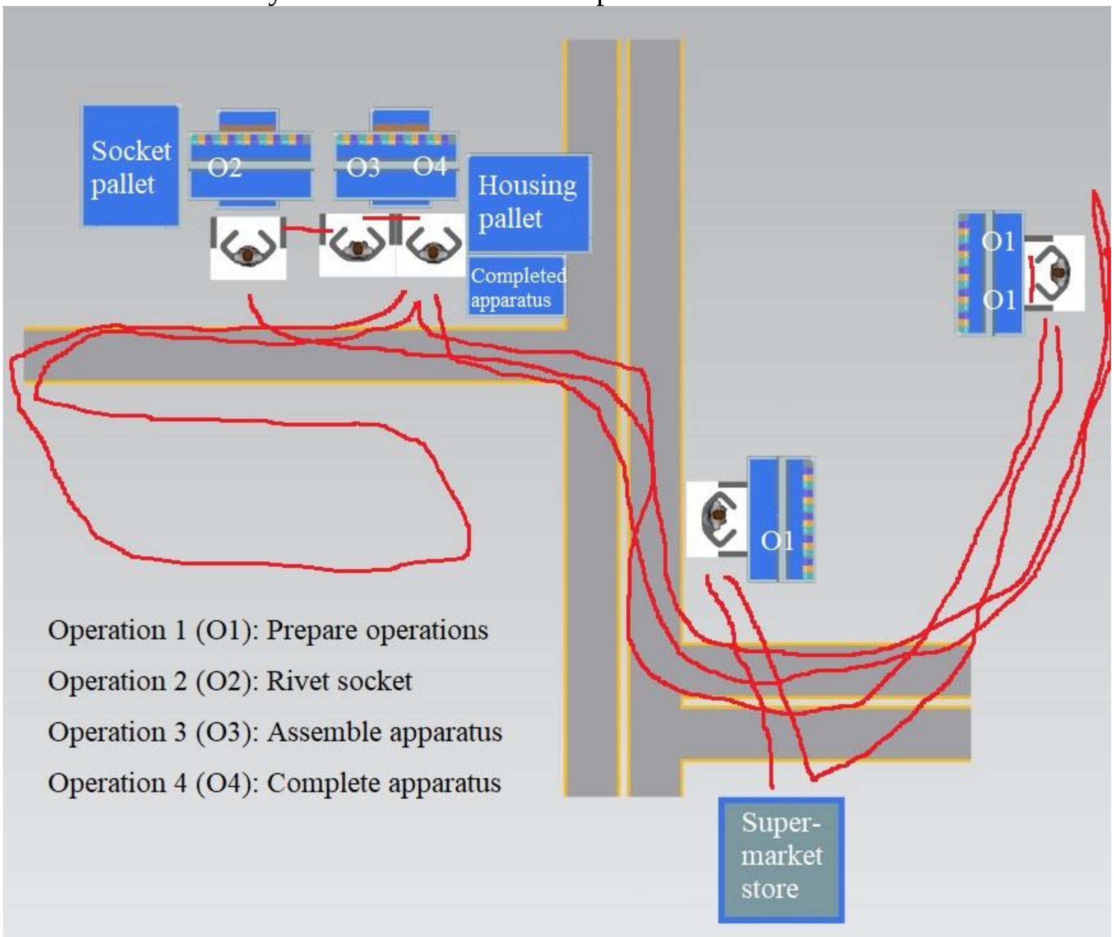


Figure 18. Spaghetti diagram of Operator's movement in red in relation to work area (created by researcher).

5.3.3 Takt principle

Total operational time:	573 s (9 minutes 33 s) to make one unit. Which equals to 6,28 units/hour
Number of steps:	39 steps.

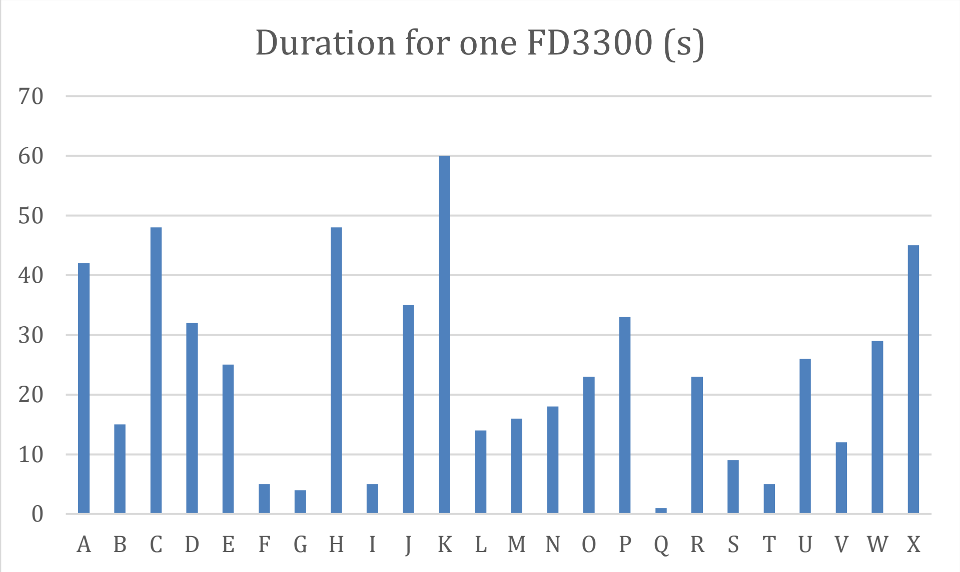


Figure 19. Tasks' CT (ABB Kabeldon).

It takes 4 hours, 47 minutes and 30 s to make 30 units which is one order.
During 2018, 3,976 units were made during 250 working days which is 1,771 working hours (2,125 working hours due to 8,5-hour shifts minus 250 hours for lunch and breaks.) That is 3.976 units made for 6,750,000 s. Production has an availability of 1,698 s on average for one disconnector. Dividing 3976 units by the number of shifts (250) gives us production volume per shift which is 15,90 Product A /shift.

Each task is performed at a workstation with a workbench, equipments and/or machine, parts, cart and chair to sit on. Each task has a CT, see Figure 19. The task time is measured by using a timekeeper. The sixth workstation illustrated in Figure 20 is an accumulation of those tasks that are done independent of a physical workstation. E.g. refilling grease or collecting parts from "Supermarket" or warehouse. Effective time available per shift is 7,5 hours. CT is calculated in Equation 8.

$$CT = \frac{Effective\ time\ available\ per\ shift}{Production\ volume\ per\ shift} = \frac{7,5}{15,90} = 0,47 \frac{h}{unit} = 1698\ sec/unit \quad (8)$$

The actual CT is however the total amount of time consumed at the assembly line to produce Product A, i.e. 573 s/unit. Which leaves us with vacant production time of 1125 s (1698 – 573). Four out of six workstations are only used to produce Product A. Meaning the vacant time for production is used by moving to other workstations to work on other products. Takt time is changed for the Operator when doing so.

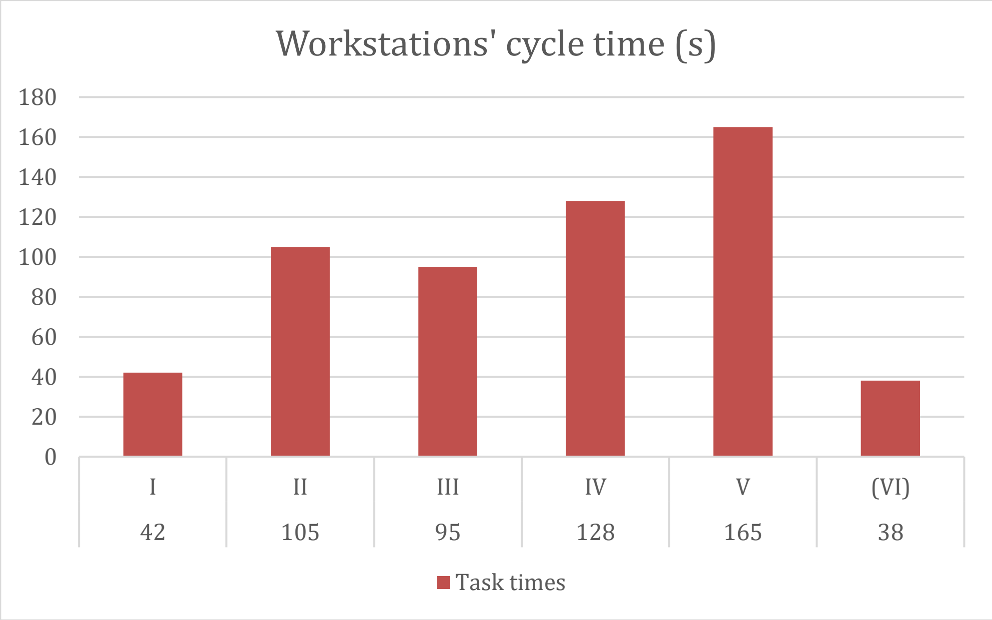


Figure 20. Workstations' CT (ABB Kabeldon).

There has been a demand of 3976 units historically. The amount of time available is based on the number of shifts during a full year. Therefor the takt time is as calculated in Equation (9).

$$Takt\ time = \frac{Effective\ time\ available\ per\ shift}{Customer\ demand\ on\ production} = \frac{27000}{15{,}90} = 1698\ seconds\ (9)$$

To determine how different the line will be as a result of changes Equation 10, 11 and 12 is calculated. Note that the CT for a single workstation is used in this calculation. Which is the workstation with highest task duration in total. In this instance workstation V has the highest amount of time used to perform corresponding tasks which amounts to 165 s. Implying that the other workstations must account for waiting to have the same takt if work is done according to one-piece-flow production.

$$Balancing\ line\ ratio = \frac{Sum\ of\ all\ task\ times}{Total\ relative\ cycle\ time} = \frac{573}{6 \times 165} \times 100\% = 58\%\ (10)$$

$$Line\ balancing\ efficiency = \frac{Sum\ of\ all\ cycle\ times}{Total\ workstations\prime\ takt\ time} = \frac{573}{6 \times 1698} \times 100\% = 5{,}6\%$$
(11)

$$Number\ of\ required\ Operators = \frac{Sum\ of\ all\ cycle\ times}{Takt\ time} = \frac{573}{1698} = 0.34\ (12)$$

58%, 5,6%, 0.34

Furthermore, Accessories' 478 inactive and active products have all takt times that have been calculated during previous projects. These form together a normal distribution of all takt times (George, 2005: 114-116). Information from the pivot table in Table 5 is clarifying to see due to the percentage of products with a takt time of 0-200 s. The takt times are visualised in Figure 21. Product A has a takt time of 1698 s and possibly 450 s during year 2020. This puts it below 1% or within 3,77% amongst the inactive and active products that are being produced. Observation of these takt times in collaboration with Operators has indications. Accessories have products with wrongly documented takt time due to insufficient analysis and being based on old routines.

Row label	Frequency	Percentage
0-100	234	48,95%
100-200	94	19,67%
200-300	24	5,02%
300-400	32	6,69%
400-500	18	3,77%
500-600	7	1,46%
600-700	4	0,84%
700-800	7	1,46%
900-1000	14	2,93%
1200-1300	5	1,05%
1800-1900	15	3,14%
3600-3700	24	5,02%
Sum	**478**	**100,00%**

Table 5. Takt time frequency (ABB Kabeldon).

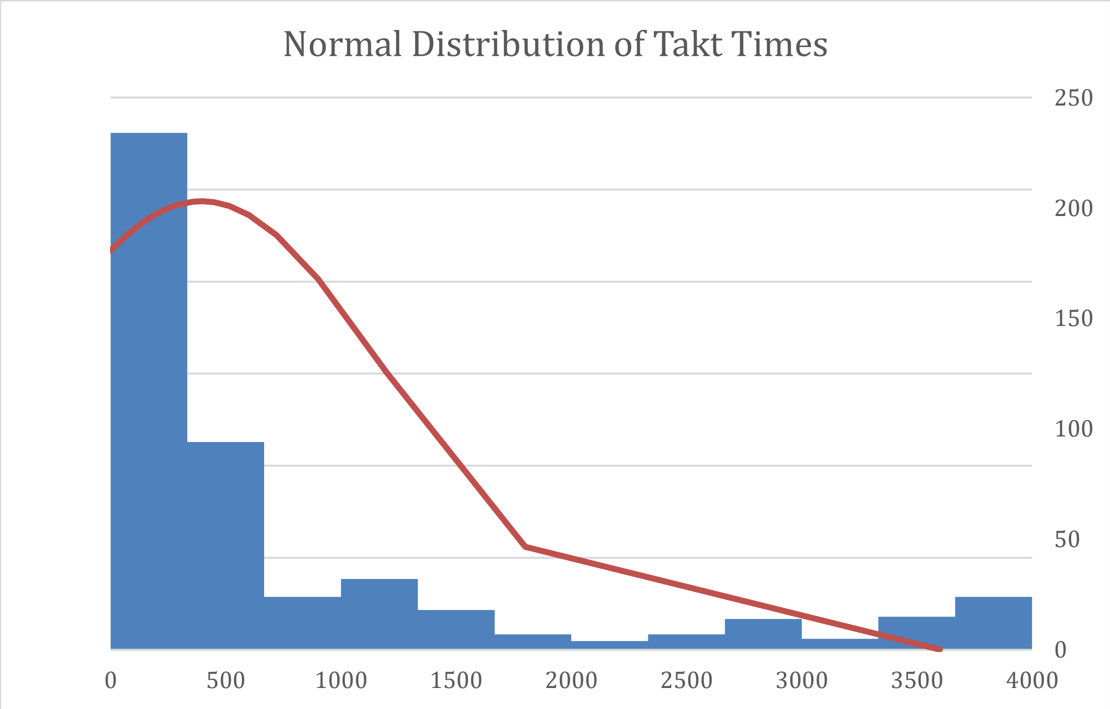


Figure 21. Normal distribution of takt times (ABB Kabeldon).

5.3.4 Zero defects principle

There have been complaints about the product several times which has been returned to the company. The PPM is calculated, and improvement of the sigma level is confirmed to be necessary.

5.4 Map

5.4.1 SIPOC analysis

The SIPOC analysis is constructed as seen in Table 7. It is made in collaboration with all stakeholders. The suppliers are externally delivering all parts which are managed in the department of Accessories. When the product is complete it is packed with installation instructions to the warehouse where it is picked and delivered directly to the customer.

Supplier(s)	Inputs	Process	Outputs	Customer(s)
External supplier (to warehouse)	3 yokes	Preparations (with 1 torque wrench with compressed air, 2 riveting machines and 1 screwdriver with compressed air)	Scrap list	Warehouse
Truck Operator	3 contact screws	Riveting of socket (with 1 riveting machine)	Finished Product A	External customer
	2 screws	Assembly of disconnector (with 3 screwdrivers with compressed air)	Work order	
	Aplenty grease	Completion of disconnector (with 1 electric screwdriver)		
	1 screw			
	1 nut			
	1 washer			
	1 socket			
	6 rivets			
	3 contact bridges			
	3 M8x12 screws			
	1 connector X			
	3 retaining plates			
	2 screws M8x25			
	1 connector Y			
	1 connector Z			
	1 screw M8x35			
	1 printed label			
	1 handle			
	1 housing			
	2 screws			

	3 attachment knives			
	3 touch protectors			
	Cardboard box			
"Supermarket"	3 connecting parts			
	3 pressure pieces			
	1 connecting rail			
	3 insulating plates			
Production Planner	Work schedule			

Table 7. SIPOC analysis (created by researcher).

As can be seen there are 29 articles and 57 parts. These parts are stored as WIP. They are large enough to be transported with one or two hands. The Truck Operator drives the material to the workstations and provides the Operator. Connectors X, Y and Z including their respective connecting parts, pressure pieces, connecting rails and isolating pads are stored in the "Supermarket". Once an order of Product A is finished, it is put in warehouse to be directly delivered to the end customer as soon as possible. After the order is finished scraps are reported for product and production development.

5.4.2 Process map

The assembly is currently at several workstations as measured in Section 5.3.1. Now it is coming in batches, all stocked to be assembled. When illustrating all steps in the operations as in Figure 22, the process can be understood to ease the analysis. The process map contains all steps taken by the Operator in collaboration with machines, equipments, instructions, parts, production planner and possibly Truck Operator. There are 11 elements in 8 colours. The elements are drawn according to Lean Six Sigma by using Lucidchart's internal software at Lucidchart.com. They include start, data, preparations, decisions, manual input, "Supermarket", stock, process (machine operation), manual operation, delay, document, terminator. (George, 2005: 34-36)

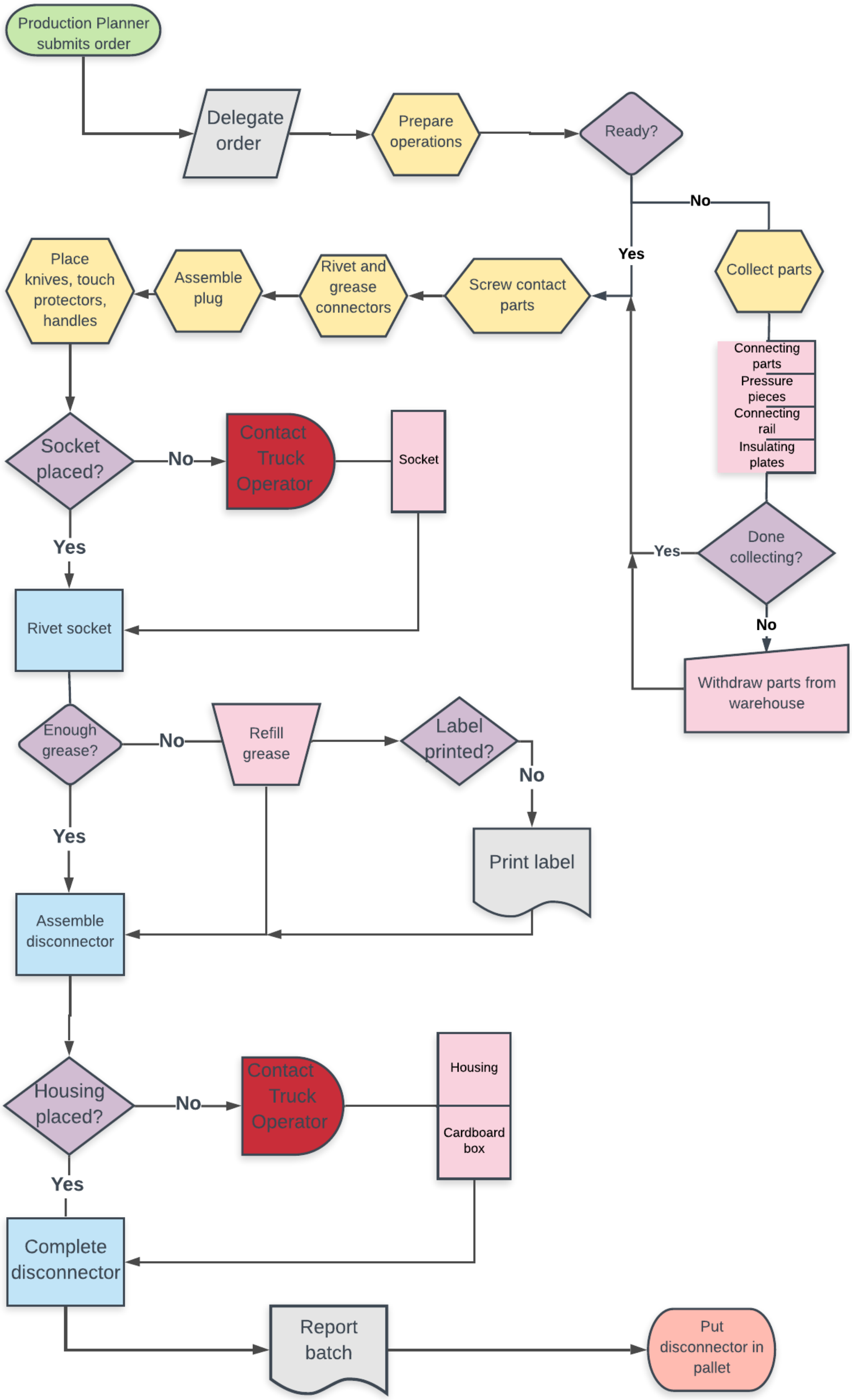


Figure 22. Process Map (created by researcher).

5.4.3 Learning according to the interviewees

Being a product that existed earlier but have been transferred to another department there are things to be learnt by stakeholders. Particularly, Operator, Truck Operator and potential Material Handler. These individuals are those who directly affects production output. If the production of Product A is changed in ways to alleviate one-piece-flow production, there are obstacles and aiding factors to the learning process.

Five out of seven interviewees believe learning takes time. They also state that habitual patterns and the willingness to change affects the time frame. Three interviewees consider time, people and money constraints as important obstacles to be dealt with. Lack of relevant and reliable knowledge can also obstruct the change process.

Four interviewees state that instructions are crucial for the learning process. Especially in the beginning when one is new at the work centre and its workstations. Three interviewees stated that having a guide or tutor is a beneficial support. Another motivator is if the consequences of the intended change are evidently good. And that change makes work easier.

The interview included room for arguments about improving learning processes. All interviewees stated that it is possible within the organisation. By attending morning meetings as suggested by three interviewees. Even though there is involvement from management, five interviewees claim that Operator and Andon should be more involved from the beginning of the LSS project and throughout the project life cycle.

Furthermore, the interviewees remarked that maintenance costs time and is deprioritised as a result of implementing QW at the department of Surface Treatment. Production Development or Quality Management can be contacted for improvements in the designated departments of Surface Treatment, Cabinet Assembly, Fusegears and Switches as well as Accessories. It is also noted that lack of space or time makes it harder for involvement because the customer comes first, i.e. production is more important than improvements.

5.5 Analyse

Based on theory and the methodology, several aspects are chosen as important to consider. It is suitable to work in conjunction with the EPPC OMS since this study is an LSS project. Thereby, complying with the system of rules that are pertained as law by higher management. However, due to the immaturity of the current business philosophy focus is on parts of the OMS that are easier to implement with greater impacts to adapt for the stakeholders. With clear intentions and objectives. To establish an effective and efficient doorway towards future objectives. According to the interviewees it is concluded that learning takes time, suggestions for gradual positive change are obviously needed, instructions are crucial and having a guide or tutor facilitates the change process. Therefore, if the time frame for an LSS project is short single-loop collective learning is prioritised. On the contrary, providing a longer time frame for the LSS project allows double-loop collective learning.

5.5.1 Root cause analysis

One part of the problem analysis is to identify causes to the problem. By communicating with stakeholders about one-piece-flow production, assembly line balancing and lean six sigma principles. They are at the same time discussing single-loop collective learning and double-loop collective learning. Clarifying what abilities are affected to change for the better.

Therefore, Operators, Co-ordinator and Andons are consulted. To perform a why-why analysis, constructed in Figure 23, on why LSS is necessary. At first, the interviewees' responses are straightforward with superficial explanation on why it is necessary. Persisting with questioning leads to deeper and deeper understanding of the causes. Finally, several root causes to why LSS is necessary to implement are revealed. Two interviewees respond similarly which results in five root causes instead of seven.

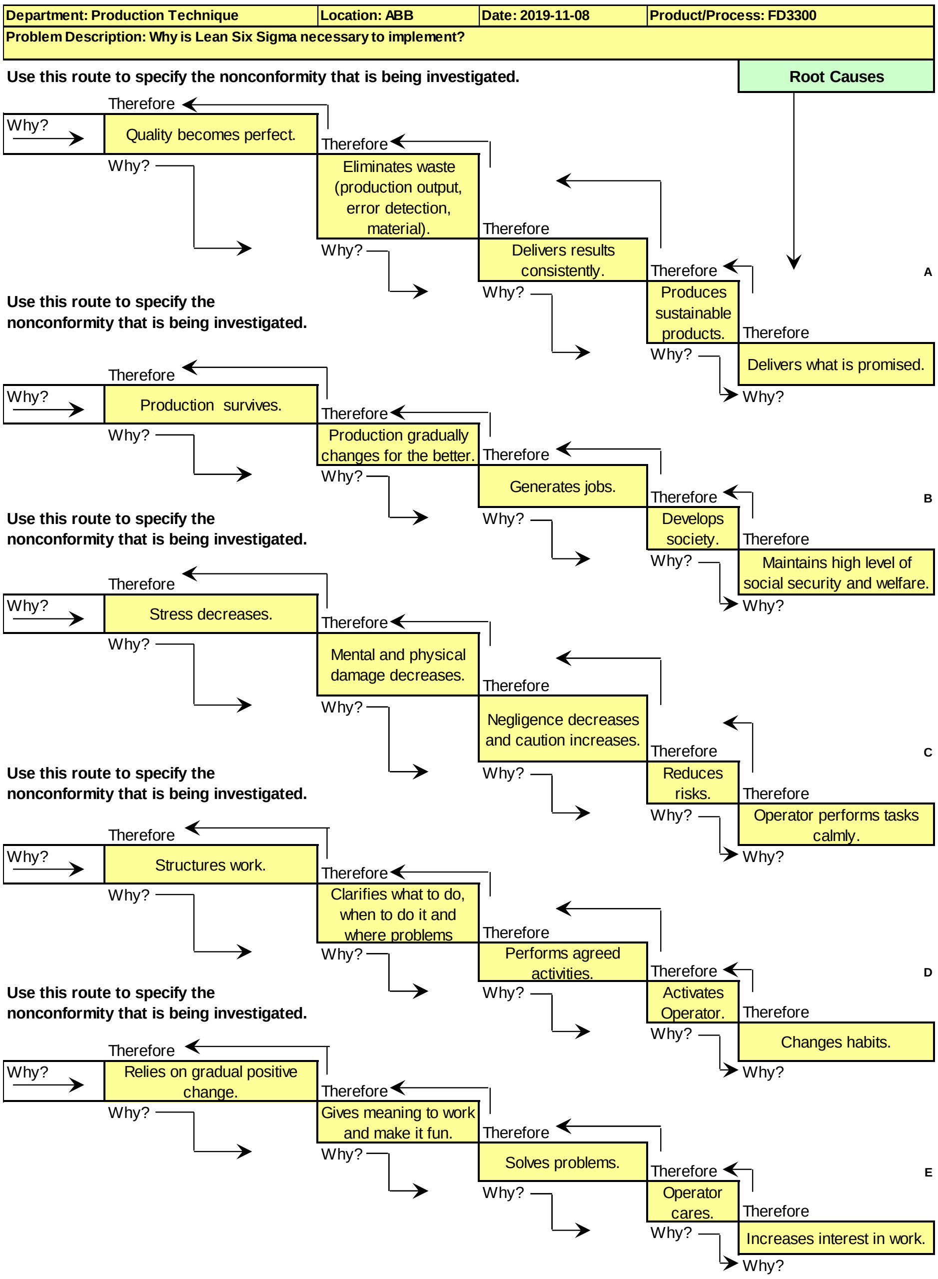


Figure 23. Why-why analysis of LSS (created by researcher).

Besides the mentioned causes of LSS within the department, the interviewees also consider other factors. Even though these factors are not further investigated they are explanatory and interrelated with previously mentioned causes. Job satisfaction and job safety increases as a result of LSS. The team manages tasks better with more flexibility in terms of qualifications and shared responsibilities. An Andon supports the team for consistent delivery on time. Less work produces the same outcome. Subsequently, not working in shifts saves costs and improves Operator's wellbeing.

In addition, root causes to the problem were also defined in the SWOT analysis. The strengths of Product A are used to manage threats that could cause more problems. Reason is that there are other products that need to be prioritised over Product A. The weaknesses are managed by taking the opportunities to make up for these root causes. Weaknesses are causing constructional and productional errors which are handled by engaging Product Development. Production Development is engaging the problem by making production stable, even and predictable. Hence, decreasing overhead costs. Sales take advantage of new market segments and new export countries are harnessed to increase revenues for these improvements.

5.5.2 Attitude towards the LSS project

The survey response rate was 66% (21 out of 32 employees who received the survey responded).[1] Only one respondent is from the department of Accessories. Therefore, there is not enough data to perform benchmarking of other departments in relation to Accessories. On the other hand, there is an even distribution (except for Cabinet Assembly where LSS is most advanced) for a fair overview of production team members' attitude towards the subjects. See Figure 24 for detailed information.

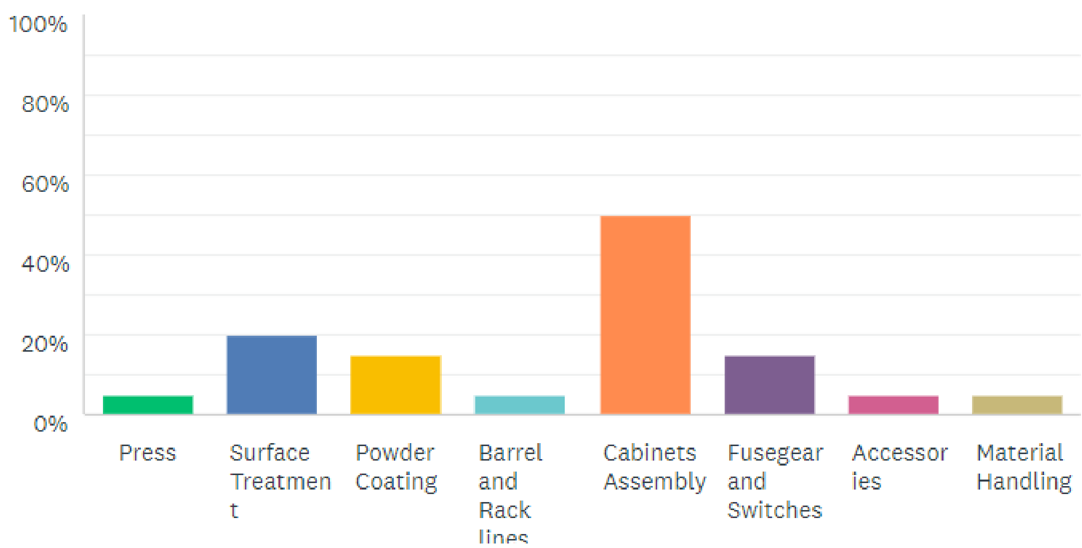


Figure 24. Demography of respondents (created by researcher).

The respondents had the opportunity to reflect on several aspects of LSS and change management corresponding to research question three: *"What are the critical success factors for such a Lean Six Sigma project?"*. According to the respondents,

[1] This survey is more successful than an average response rate of 30-40% (O'Leary, 2017: 230).

collaboration is the most agreed upon factor to facilitate successful changes towards one-piece-flow production.

There are several points made that entail a general agreement on several statements. Throughout the survey, the respondents answer positively to six out of seven quantitative questions.

There is a positive view towards changing, faith in positive outcome of LSS project and the ability of LSS in making work more practical for the team member. The respondents also consider learning and feedback from management as important within LSS projects. One-piece-flow production is perceived as better way to work as compared to working with batches. A combination may be the best option by producing smaller batches. Hence, there is still a rapid flow of production.

One statement varied strongly in terms of responses, surpisingly even over the whole scale from strong disagreement to strong agreement. It concerned the issue of knowledge about LSS from the respondent's perspective seen in Figure 25.

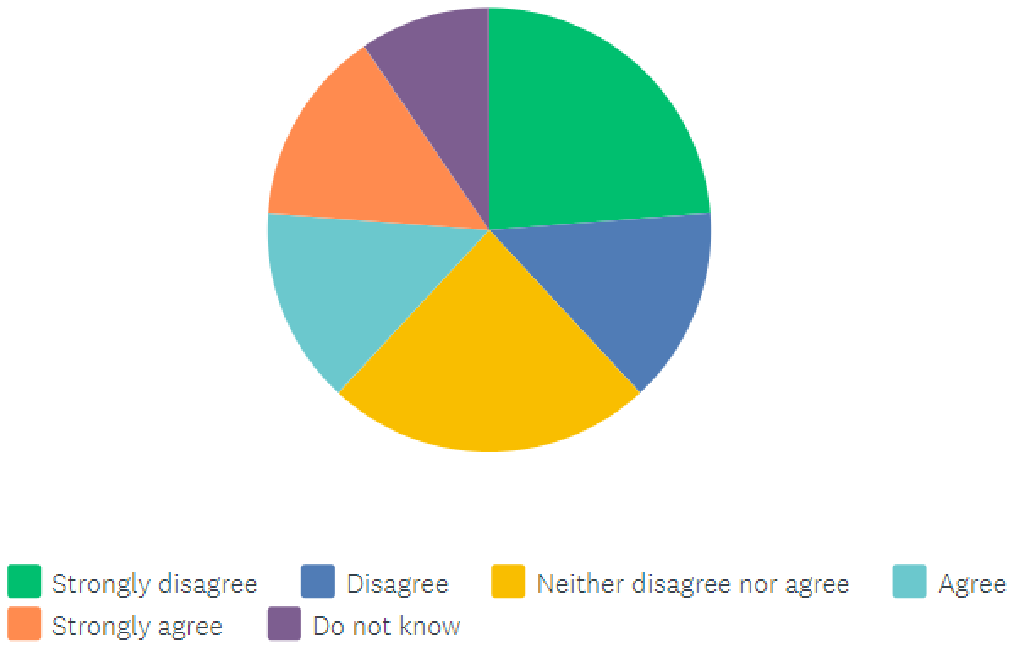


Figure 25. Lack of knowledge about LSS at shop floor (created by researcher).

Even though there is only one respondent from Accessories he/she still makes up 13% of the department. His or her opinions coincides with the majority. Except for the difference between batches and one-piece-flow production. In this instance, he/she differs to the majority by strongly disagreeing about the superiority of one-piece-flow production compared to batch production. He/she is also one of those who states that he/she is not lacking knowledge about LSS.

Furthermore, responses encompass gradual positive change. All respondents share one instance of but fewer and fewer share additional instances. They list management of departments, equipped operations as well as people engaging with each other and his or her work in a healthy way. Also, resource management, continuous flow of production and having right quality from the beginning as important aspects of changes in production. One instance is shared by several respondents, emphasizing the importance of having a dedicated team, exclusively for larger change initiatives.

Consequently, 76% of all respondents share the perception of gradual positive change at his or her work centre. Those who have experienced LSS consider the changes as being for the better. Resulting in more organisation of work and material. Gradual positive change is expressed acceptable at most work centres. Few believe that there is more to do. One respondent believe that he/she is not allowed to participate.

Consequently, the conditions are considered as good from the Operators and Andons' point of view. In addition, there are more forces that work in favour of the project to work towards one-piece-flow production than against this development. The 15 forces that are driving the changes are enforced by using the positive attitude. The 11 restraining forces are diminished by communicating consequences of root causes. According to appropriate communication method. To manage stakeholders successfully and working through forces one by one. These forces are already categorised according to five aspects of study and root causes which simplifies the functional correlation of a force with a stakeholder.

5.5.2.1 Operators' and team leaders' opinions about Lean Six Sigma

The interviewees all responded that he/she can be partially flexible to do work in his or her own way. However, the work activities are predefined. Three out of seven stated that

> *"we adapt to the circumstances if an Operator is absent or if there are other activities planned for me which is done when production is sure to reach daily target." (ABB Kabeldon)*

There is the same meaning for those who work in Accessories and those in departments already deploying Lean Six Sigma. Thus, there is a shared understanding for why it matters to have Lean Six Sigma because of

> *"Right quality in right time", "Improvements", "It is satisfactory if everything works.", "Structure and tidiness." (ABB Kabeldon)*

Moreover, the benefits are according to the interviewees:

- Right quality, from the beginning to the end of the production (two interviewees).
- Control over predictions, material flow and decision-making based on facts.
- Saving workspace.
- Better results of output in the assembly line.

On the other hand, the disadvantages are said to be:

- Time consuming at first but saving time when it is done right (two interviewees).
- Hard to apply to simple assignments such as packing a screw or screwing a tile of wood (two interviewees).
- Dependent on a continuous flow of material and work activities (two interviewees).
- If something happens or material is insufficient, operations stop (three interviewees).
- Allocation of resources are hard to decide in the beginning.

- It is easy to get locked in the same mindset if improvements aren't made (two interviewees).

Another aspect of LSS is how it can be successful. According to the empirical data five interviewees prescribed stakeholder involvement at an early stage of the project. Success was asserted to people, especially the Process Owner, with the right expertise. By communication between stakeholders and enough team members to carry out the project. Enabling communication to manage forces for and against changes with clear roles and responsibilities.

To ensure, or at least increase the probability of, long-term effects there are more aspects to consider. Change must be proven to make things better according to three interviewees. They also claimed work should become easier. That longevity is because of enthusiastic, driven, innovative and visionary leaders. Also, that results become more reliable. Frequent, gradual positive change is a necessity for LSS to continue according to four interviewees. The new way must be trusted so people believe in what they do and rely on the standardised way of doing things.

5.5.2.2 Change Management in LSS project from Operator's point of view

In Sections 2.1.1-2.1.3 it was described that operations, people as well as quality need to be managed when the department is changing. Empiricism, from interviews, surveys and observations, entails how to manage these entities for a successful LSS project. Easier change management is a result of a new process which is easier to operate than the previous one. Even though it might be boring at first, it should be challenging enough to be fun and personally developing. The Operator must accept the process and realise he/she can overcome the challenges. The Operator must also realise having comfort in how things are done can be dangerous on the long-term because a person can become lazy. He/she and other stakeholders must be prepared and prepare each other by testing the process step by step, according to two interviewees. Departments other than Accessories advise team members in Accessories to trust in that the new way is better. And that there are morning meetings to communicate about difficulties and improvements.

When receiving the changes two interviewees assert that reading instructions at the workstation(s) help. However, none of the survey's respondents suggested specifically instructions as helpful. Even though how a change is received differs depending on the situation. Additionally, it is supportive to have the whole picture of what is expected to embrace the change successfully. Interviewees tend to be both reactive and proactive to new changes by asking around and waiting for instructions (four interviewees). Two out of seven interviewees only ask somebody who is experienced, and one interviewee claimed that he is curious about changes affecting his workday.

Above and beyond, there are support factors for adaptation to new routines.

- Instructions (two interviewees).
- Education: both individual and collective learning depending on how many that are to be taught (three interviewees).
- Having fun.
- Appropriate equipments.
- A mentor, guide or tutor (two interviewees).
- Having a dialogue on a regular basis.

- Following norms such as the Code of Conduct.
- Colleagues, especially those who are engaged in doing what is necessary and not only what is required.
- Co-ordinator or Andon.

Consequently, there is a strategy in mind for Accessories from the Operators' and Co-ordinators' point of view. Success is more probable if the team is involved and all stakeholders are listened to. Two interviewees suggested having robots and automated tasks to decrease disturbance in the process.

With Product A in mind, it was suggested that the transition from manual assembly line to one-piece-flow production would be successful. *"By simplifying the product with less parts."* and *"by applying it to a relatively complex process instead of a process that's too simple."*. It was also advised that material must be fed steadily to the assembly line to keep the takt and flow of the process in order.

An interviewee with previous experience with LSS in Cabinet Assembly department stated that *"variation and rotation at workstations facilitate productivity and job satisfaction."*. Another interviewee also contended, with the Operator in mind, that *"by focusing on one task a time work is easier to manage with less complications such as stress."*.

5.5.3 Wastes

As a result of analysing each task's value, the value-add chart in Figure 26 is created. 15 s are non-value-adding. That is, muda which is eliminated without affecting the customer negatively. 80 s are business non-value-adding, mura and muri in other words, which are diminished. The rest of the 573 s of which are 478 s that are value-adding activities are improved to decrease CT.

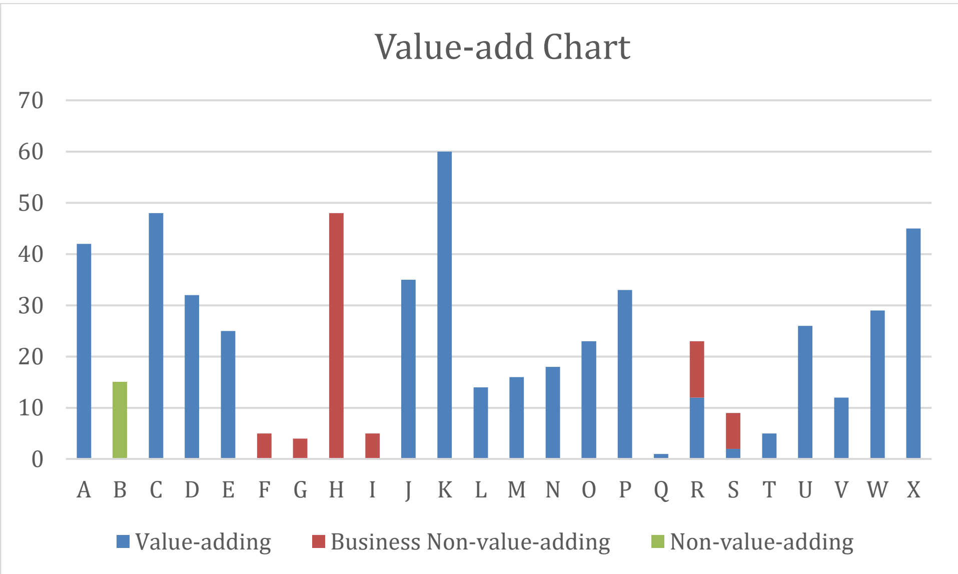


Figure 26. Value-add chart (created by researcher).

5.5.4 Assembly line balancing

The precedence of tasks is illustrated in Section 5.3.1.1. There is a relationship between certain tasks. These tasks are more interdepended during the beginning, middle and end of the process than in other stages as can be seen. Task A, B, F, G, H, J do not have predecessors. The current capacity of the assembly line is 1,698 s/unit.

There is a hypothetical situation with a number of 15,000 disconnectors exceeding the 2020 prognosis of 5,065 with 10,000. When 15,065 Product A is demanded, 60 units must be made each shift. The takt time, calculated in Equation 14, is then 450 sec/unit. Nevertheless, current CT of 573 s must be lower than takt time. In order to produce the demanded output by customer and satisfy his or her needs. For this to be possible the assembly line is adjusted to the opportunities of production demand.

$$Takt\ time = \frac{Effective\ time\ available\ per\ shift}{Customer\ demand\ on\ production} = \frac{27000}{60} = 450\ seconds/unit \quad (14)$$

$$Desired\ CT = \frac{Effective\ time\ available\ per\ shift}{Production\ volume\ per\ shift} = \frac{27000}{60} = 450\ sec/unit \quad (15)$$

For this to be possible with objectivity, the minimum number of Operators is evident to calculate. By dividing CT with takt time there is a need for 1.27 Operators (573/450 sec). By applying this theoretical index to reality, it must be rounded upwards. Thus, two Operators are needed, sharing the workload. If the work is distributed evenly CT is diminished to 287 s (573/2 sec) which is below takt time. Thus, production output meets customer demand with vacant time of 163 s to utilise when production deviates due to delays or errors. E.g. when production is short of material as illustrated in the Process Map. When sockets, housings or cardboard boxes are insufficient the Operator or team leader must contact the Truck Operator to refill buffers of items.

Since the CT cannot be reduced completely to 450 s from 573 s there is another option. The CT can be reduced by allocating work to several workstations operated by several Operators in a one-piece-flow production. There is the department of Fusegears and Switches where this type of production is already in place. The assembly line has a takt of 23 and 26 s respectively at five workstations excluding the work of Material Handler and Andon at moving workstations. Implying that Product A process must be divided into operations with equal CT to fit in. Product A has value-adding operations with task times ranging from one to 60 s, indicating that certain tasks require more time than what is the prerequisite for products at Fusegears and Switches. Nine tasks are concerned with this obstacle. Four tasks, to be precise, can be reduced. With a more experienced Operator, since the measurements were made on a low experienced Operator's work. Also, better feed of material e.g. thanks to Kanban train by which material delivery to workstation is outsourced to Material Handler. Making one task irrelevant to F&S's assembly line. 16 tasks consume less than 26 s which fulfil prerequisites. However, these tasks are spread out during the process which necessitates a more complex process divided into both one-piece-flow production, and batch production done singularly by manual assembly.

Consequently, a third option is to adapt the assembly line to the takt time by assigning tasks to several stations, each operated by an Operator respectively. Resulting in one-piece-flow production. The minimum CT can be 60 s to perform a task. There are currently five workstations at four assembly workbenches and one workstation in motion to gather transforming resources mostly. In total there are six workstations. If these workstations are operated independently the CT for each workstation is 96 s

(573/6) on average. Considering the resources and the assembly line design, this is not possible to pursue unless the assembly line is redesigned. There is limited space to work on and limited space for equipment at each assembly workbench. Hence, it is not possible to delimit it anymore. Also, even though same type of equipment is used at different workstations, the changeover time for equipment accessories, such as bits to a screwdriver, is too high between operations to effectively use the same equipment for different operations.

Nevertheless, the third option is by doing the assembly line balancing independent of current situation. To elaborate a new design or new sequencing of tasks. The precedence diagram is drawn, the takt time is calculated to 450 sec/unit. The assignment heuristic implies assigning tasks in the order of longest operation time first. This is relying on the theoretical number of workstations. The sum of all task times is 573 s. If one person does all tasks as is done, production will not meet customer demand. Therefore, the theoretical number of workstations is calculated by dividing 573/450 s which is 1.27. Since a workstation is fixed the figure must be rounded up resulting in two workstations to meet customer demand. Resulting in a one-piece-flow production combined with smaller batches of e.g. five units compared to the previous batch of 30 units.

Assembly line balancing does also affect the assembly line design. That is, how the products are assembled. According to the interviewees there are several differences between one-piece-flow production and production made in batches. A consensus about the differences is not found. Based on work in the Press and Surface Treatment department an interviewee claims that downtime is better managed in one-piece-flow production. However, material is harder to manage. Another interviewee states that:

> *"the chance of making a mistake is higher because a task is performed separately for each product to be assembled. When working with batches the task is performed simultaneously for all products in the batch. With less movement and time. It is better with one-piece-flow production because production is more predictable and easier in a way with less stress according to a takt." (ABB Kabeldon)*

A third interviewee concurs that production has a continuous output with products on demand rather than waiting for the full batch to be completed, step by step.

According to an interviewee in Cabinet Assembly department, where people are already familiar with LSS, there is possibility for more variety in production when having one-piece-flow production. Also, production output has doubled due to one-piece-flow production compared to batches. Material is ready when needed and placed at all workstations instead of different places.

Two interviewees disagree on the learning practices. The first contends that there is no difference in learning the work activities. Whilst the other claims that:

> *"it is easier to learn and easier to teach what is to be done at each workstation separately. The learning is progressive instead of all at once to be able to perform."*. On the contrary, two interviewees agreed that *"Product A is possible to produce in one-piece-flow production if there is a larger volume*

because it goes faster to do so with batches when the volume is small." (ABB Kabeldon)

Consequently, there is a strategy in mind for Accessories from the Operators' and Co-ordinators' point of view. There are several factors which can determine if the LSS project is a success or a failure. Clear instructions and routines are in one way or another prescribed as a crucial tool for the learning process due to changes in the assembly line. Education and/or training are also listed. Success is more probable if the team is involved and all stakeholders are listened to. Two interviewees suggest having robots and automated tasks to decrease disturbance in the process.

With Product A in mind, it is suggested that the transition from manual assembly line to one-piece-flow production is successful. This was exemplified by three interviewees stating *"…by simplifying the product with less parts."* and *"…by applying it to a relatively complex process instead of a process that's too simple."*. It is also advised that material is fed steadily into the assembly line to keep the takt and process flow in order by the same interviewees.

An interviewee with previous experience with LSS in Cabinet Assembly department states that *"variation and rotation at workstations facilitate productivity and job satisfaction."*. Another interviewee also contends, with the Operator in mind that *"by focusing on one task a time work is easier to manage with less complications such as stress."*.

Finally, the interviewees are asked about obstacles and challenges with the changes preceding one-piece-flow production. Interviewees from departments other than Accessories explain that downtime, absenteeism, knowledge management, lack of resources and especially people (five out of seven interviewees), convincing staff and having the time to learn are obstacles. In addition, four interviewees claim that adapting to change is difficult at first due to chaotic circumstances with new way of working and faster pace of doing. Both interviewees from Accessories highlight the importance of having a volume that is big enough as to make it feasible and profitable.

Thus, all interviewees have knowledge about one-piece-flow production. Even though not all have yet experienced working in such a work setting.

5.5.5 Q6 model

The Q6 model includes processes that are aimed to be implemented one by one or where it is suitable. As this study is a gateway for Quality Wins/LSS to be used as an operations management system, there are some processes that fit Accessories to use based on theoretical and empirical data. With regard to the company report prescribing the Q6 model only Q1.3 has a prescribed tool to be used.

During the Select phase it is declared that there are forces that affect the legality aspect of an LSS project. The project changes culture, changes habits and stakeholders must be convinced. On the bright side, the project aligns department with rest of the organisation, helps employees stay current with industry standards, increases job satisfaction and changes work, reasonably, for the better. All processes of the Q6 model are affected by these forces. Q1.1, Q1.2, Q1.3, Q4.1, Q6.1 supports the current issues at the shop floor.

Q1.1 (Quality Gates) is necessary according to middle management which is advocating for transparency and simplification of operations. In addition, according to the zero defects principle the PPM is measured to be lower than desired by top management. By reviewing customer complaints reoccurring problems is a fact, for instance a handle being missing from the final product. This issue and others are not eliminated due to non-transparent communication. Also, lack of prioritisation leads to no scheduled attempts to eliminate causes of defects.

Q1.2 (Andon) is necessary to facilitate the learning process. Which is corroborated by four interviewees. Also, a reaction process is employed to alleviate Operator from tasks that disrupt the modus operandi such as insufficient material, quality issues or disturbances in production. For instance, excess team members are decreased when an Andon oversees the team daily. S/he plans daily activities and executes necessary activities that may disrupt production. Whether it be a problem that needs to be communicated to other departments or an LSS project that requires insight from production such as this feasibility study. There are tasks that are prepared for Product A's operations. By collaborating with Material Handler an Andon do so to make the process leaner according to the pull and flow principle.

Q1.3 (Quality Feedback Loops) is beneficial to employ to reduce deviations in production. The global ABB provides two activities for this intervention. "Quality Issue Alert Sheet" contains information about the detection, description, facts and people related to the problem. "Alert & Fix" is used to document solutions of the issues occurring due to deviations. It can be used for documentation purposes of the Product A assembly process. Thus, its process is equal to other products being assembled at Accessories. Through a standardised way of managing issues in a methodical manner. So as, there is a shared understanding of what is required to solve problems or gradually changing operations for the better.

Q4.1 (Standard Operating Instructions) is an expressed need by four interviewees and no respondents. If Product A is transferred to a one-piece-flow production assembly line from the current manual assembly line. Hence, malpractice or errors in the process are proactively treated. Learning the new process is also supported. So as, the operations are identically executed independent of who the Operator is. It enables transparency and understanding of the desired performance at each workstation.

Q6.1 (Meeting Structure) alleviates knowledge management by and for the whole production team. Knowledge is created, acquired, and transferred in collaboration from the start. Focusing on single-loop and double-loop collective learning simultaneously. The process of gradual positive change generates a possibility for modifying behaviour to reflect new knowledge and insights regularly. As well as aligning beliefs about what efficient and effective production entails. I.e. aligning these aspects with overall strategy and the strategy of Accessories in particular.

It is necessary due to the need for continuous checkpoints throughout the change project until the agreed upon future state is accepted. Communication of suggestions is evident when Operators, Material Handler, Andon, Production Development

Specialist, Production Planner, Safety Representative, Production Supervisor and Truck Operator all gather to communicate current events. Management has also the opportunity to motivate and educate team members to maintain even development according to takt time in production, regularly. Consequently, enforcing the operational, driving forces and mitigating the operational, opposing forces daily. Nevertheless, it is primarily used on a short-term basis, according to observations and interviews, to solve daily matters.

5.6 Improve

5.6.1 Benchmarking

5.6.1.1 Various technical and operational solutions

Inspiration comes from other departments at the company. First Pass Yield (FPY) lists are used. The assembly is separated into two units thanks to a buffer. The production has light visualisation aiding the Operator. To balance the line and quality check as well as quality assure the product that is to be sold to the customer. Tasks that are planned exactly according to theoretical results are realised by using a monitor. It visualises remaining time of each task and overall operation. Articles and places for them are also visualised to reserve locations and simplify understanding of assembly procedures and tool names. Automation is enabled due to sorters. There are instructions and feedback tools to know a person is doing things correctly. E.g. a target board is used to differentiate process of different products with respective takt time. There is an Andon. SMED (Single Minute Exchange of Dies) is adopted to decrease set-up or changeover time in between processes. There are ergonomic lift tables. Combined fixtures are used for different models of the same product.

5.6.1.2 Logistics and material handling

A Kanban train is used to optimise internal logistics. At the assembly of cable distribution cabinets, materials for product type are fed into the assembly line after a dedicated Material Handler has checked respective production “receipt”. In the receipt it is stated what material (parts) and the amount of material that the Material Handler needs to place in the wagon. The train is driven by the same person throughout the shift. Andon decides the order of production flow of products that are to be assembled at the department. Materials are delivered by the Material Handler to the Operator every 30 minutes. Separate shelfs are used vertically to increase space utilisation. All material is stored at one place as the “Supermarket” within Accessories. Pallet rims is important to consider if the material must be often accessible for an Operator. Without the aid of a Truck Operator The warehouse closest to F&S and Accessories has maximum number of pallet rims.

5.6.1.3 Equipment and workstation

Equipment is provided belonging to each work centre which has its own takt. Operators work at both sides of the assembly line in a straight line. Each task is processed separately from workstation to workstation. All operations fit within the semi-automated assembly line. Work practices are standardised. Working while standing instead of sitting saves space for material and makes the Operator more flexible in movement between workstations. Pre-assembly is done for tasks having longer CT than takt time such as sockets. The team consists of individuals working independently at each workstation to create a pull system. Each cart is continually filled with material from the warehouse. Each cart fills in turn each cell based on the product to be produced and the flow of production. Few tools are used since the Operator is mostly using his or her hands. All tools are in one place based on the lean method 5S (sort, straighten, shine, standardise, sustain). Robots performing certain tasks are also assigned the tool exchange. Bits for tools are exchanged manually in-between processes of product.

5.6.2 Suggestions for gradual positive change

5.6.2.1 Suggestion 1: Balancing assembly line

These changes comply with the flow and takt principles when the line is balanced. The business non-value adding tasks are diminished:

- Tasks F and G: Handles, attachment knives and touch protectors are delivered according to the batch or order that is to be produced. Currently, there is a batch of 30 units per order. Thus, 90 attachment knives as well as 90 touch protectors and 30 handles are pre-packaged by Truck Operator when it is packaged in the first place. As a result, nine s, including a movement of four steps, are saved. There are no predecessors, so these tasks are done independent of other tasks.
- Task H: This task is done independently during pre-assembly saving 48 s including two steps.
- Task I: Is eliminated by performing it simultaneously as Task E when placing connectors in bins. Thus, five s are saved including two steps.
- Task R: The part of the task where the socket is placed into a fixture is BNVA. These 11 s, including two steps, are diminished. By taking away the fixture and using the fifth fixture as holder. Hence, saving space as well which is used for grease.
- Task S: Seven s, including four steps, are diminished by having the refilling done at the workstation where Task R is performed.

The non-value-adding tasks should be eliminated:

- Task B: Is eliminated by using the Kanban train which feeds material into the line. This saves 15 s and one step for the Operator.

In total, 95 s and 15 steps are saved from Operation 1 and Operation 3. Operation 2 and Operation 4 are not affected by these changes. Sum of all task times are therefore decreased to 478 s (573-95 sec). Implying 17% of total time consumption has been decreased (95/573 s). Figure 29. illustrates the new workstation time consumption with each workstation having its own CT. Earlier the CTs were ranging from 38 to 165 s. They are now ranging from 2 to 117 s with more even distribution between each workstation. Almost eliminating movements at the moving workstations.

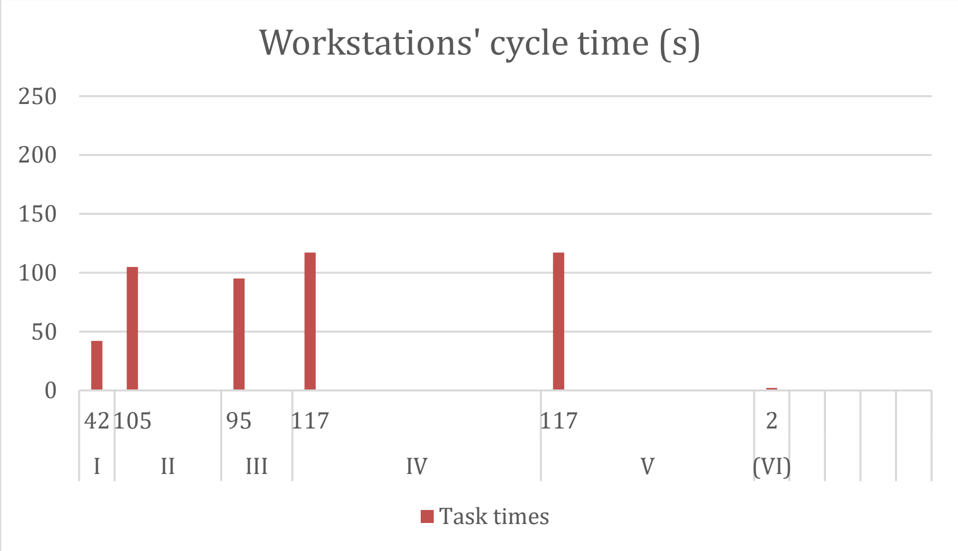


Figure 29. Workstation CT after waste analysis (created by researcher).

$$Balancing\ line\ ratio = \frac{Sum\ of\ all\ task\ times}{Total\ relative\ cycle\ time} = \frac{478}{6\times117} \times 100\% = 68\%\ (16)$$

$$Line\ balancing\ efficiency = \frac{Sum\ of\ all\ cycle\ times}{Total\ workstations'\ takt\ time} = \frac{478}{6\times1698} \times 100\% = 4{,}7\%\ (17)$$

$$Number\ of\ required\ Operators = \frac{Sum\ of\ all\ cycle\ times}{Takt\ time} = \frac{478}{1698} = 0.28\ (18)$$

Compared to the original circumstances the wastes are evaluated. Balancing line ratio increases with 10 percentage points. Line balancing efficiency decreases with 0,9 percentage points. Meanwhile, 0,06 less Operators are required.

The Truck Operator confirms counted handles, attachment knives and touch protectors (Task F and G). Being relatively large parts. Relieving the Operator from doing so. By using a tally counter, see Figure 30. Instead of relying on the mind to do so with the human factor due to stress, tiredness or negligence. However, each product must be counted individually instead of in clusters which may take more time.

Figure 30. Tally counter (Amazon.com).

The Operator changes movements by performing Task I simultaneously as Task E without going back and forth. This necessitates clear calculation of the parts. By accepting and remembering the repeated pattern of calculation or by using the tally counter.

The refilling of grease for Task S is done at the workstation for Task R. Due to changes on Task R in suggestion four. By placing a box of grease within the workstation which lasts for 6 orders of 180 Product A. The only disadvantage is that a new box is used, taking up more place in general. The Operator also moves less indicating more stationary work which can ergonomically be negatively experienced.

The Kanban train used at Fusegears and Switches is passing the workstation for Task B. Therefore, the Material Handler feeds the material (10 articles). Thus, the Operator remains focused on performing value-adding tasks. A disadvantage is having more material in the train which can affect the accessibility of other products' parts.

These changes enables use of Q4.1 with updated instructions on how to operate the process. It upgrades the Operator and his or her work. It requires reiterating the changes to change behaviour and adapt to overcome the old habits hindering the gradual positive changes. A disadvantage of updated instructions is mixing up old instruction with new instructions which can be confusing.

5.6.2.2 Suggestion 2: Re-balancing assembly line

These changes comply with the pull and takt principles when the line is re-balanced. According to the waste analysis the non-value-adding activities are pursued to be eliminated, value-adding activities improved, and business non-value-adding activities diminished. The third assembly line balancing option that was analysed is developed below to understand the consequences of positive gradual change that the process of Product A assembly is subject to.

The tasks are planned to be managed according to the waste analysis in Section 5.6.2.1. Therefore, the assembly line balancing does not include certain tasks which are eliminated or done externally, as illustrated in Table 8 and Figure 31. With regards to Tasks B, F, G, and H. The workstations' updated CT is illustrated in Figure 32.

Equipment	Station	Task	Task time	Time left (450)	Task ready (A, J)
1 torque wrench with compressed air, 3 fixtures, 3 riveting machines, 1 screwdriver with compressed air, "Supermarket", cart	I	A C D E J K	42 48 32 25 35 60	208	C, J D, J E, J J K L
2 fixtures, 1 electric screwdriver, 3 screwdrivers with compressed air	II	L M N O P Q R S T	14 16 18 23 33 1 12 2 5	214	M N, O, P, Q O, P, Q P, Q Q R S, T T U

		U	26		V, W
		V	12		W
		W	29		X
		X	45		

Table 8. Assembly line balancing (created by researcher).

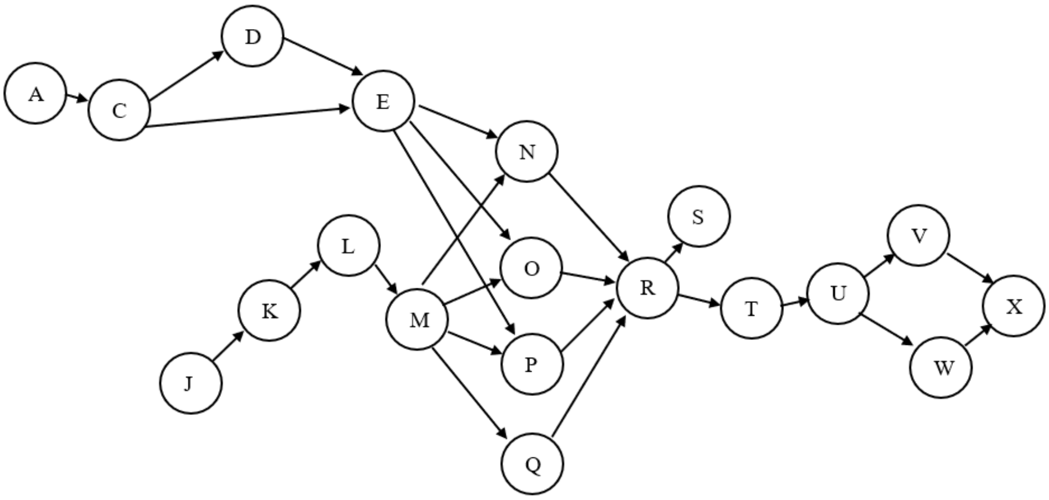


Figure 31. Alternative precedence diagram (created by researcher).

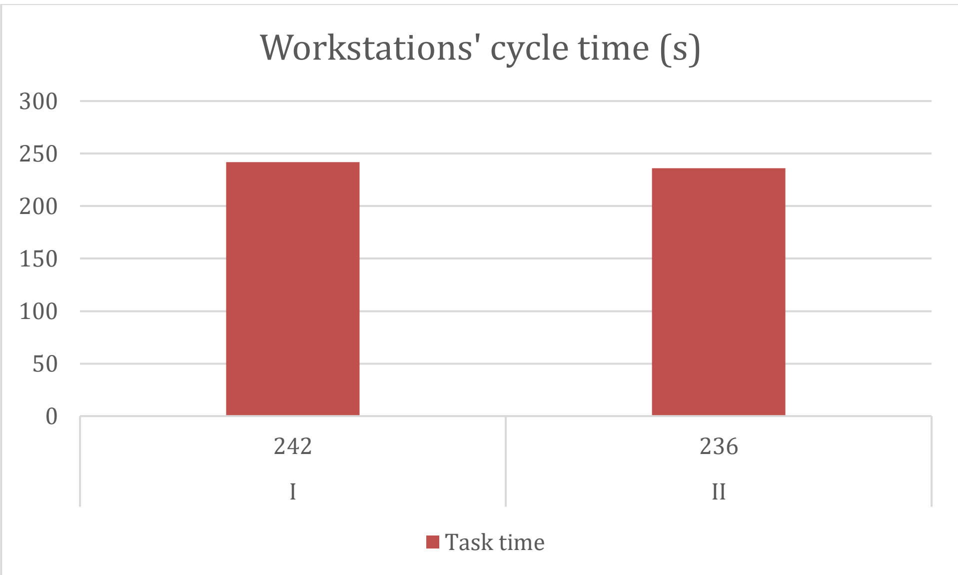


Figure 32. Workstations' CT after balancing (created by researcher).

Furthermore, balancing line ratio, line balancing efficiency and number of required Operators are recalculated, see Equations 19-21. Compared to previous results, the balancing line ratio has increased with 26 percentage points. Line balancing efficiency has increased with 47,5 percentage points. In addition, 0,72 more Operators are required. The importance of experience for this instance necessitates another Operator. If an Operator can work 6% more efficient the number of required of Operators is reduced by 100%, from two Operators to one Operator.

$$Balancing\ line\ ratio = \frac{Sum\ of\ all\ task\ times}{Total\ relative\ cycle\ time} = \frac{478}{2\times 284} \times 100\% = 84\%\ (19)$$

$$Line\ balancing\ efficiency = \frac{Sum\ of\ all\ cycle\ times}{Total\ workstations'\ takt\ time} = \frac{478}{2\times 450} \times 100\% = 53{,}1\%\ (20)$$

$$Number\ of\ required\ Operators = \frac{Sum\ of\ all\ cycle\ times}{Takt\ time} = \frac{478}{450} = 1.06\ (21)$$

The downside with this approach is the fact that the Operators must be flexible in operating the equipment. Tasks are done at both workstations by alternating tasks between each other. Task A is done by Operator 1, Task C is done by Operator 2, Task D is done by Operator 1 and so on. Except for Tasks N, O and P where the same equipment and space is used for iterating the assembly of all three connectors.

However, production is continuous with smaller batches, doing five Product A at a time. In addition, there are a torque wrench, a screwdriver, three fixtures as well as three riveting machines at the first workstation. At the second workstation there are two fixtures, three screwdrivers and one electric screwdriver. Hence, the workbenches must be larger to fit all equipment compared to the ones used today. Including the space for all articles and parts that are used to produce Product A.

5.6.2.3 Suggestion 3: Combined fixture

These changes comply with the zero defects and flow principles. The first three fixtures are used for preparations (Task A, D and H) at different workstations, see Figure 33, Figure 34 and Figure 35. These fixtures are combined to one fixture to perform all preparations at the same workstation, see Figure 36. To save workspace, movements and task time whilst making operations flow evenly with less distractions due to movements or other operations performed at the same workbench. The required equipment to operate fixtures (one torque wrench with compressed air, two riveting machines, one screwdriver with compressed air) is allocated to one assembly line bench. The articles and parts are also allocated to the same bench by creating a flexible workspace. Boxes with smaller sizes, compared to the current ones are used vertically. They are placed on top of each other to fit the workspace available on the bench.

Figure 33. Fixture one (photographed by researcher).

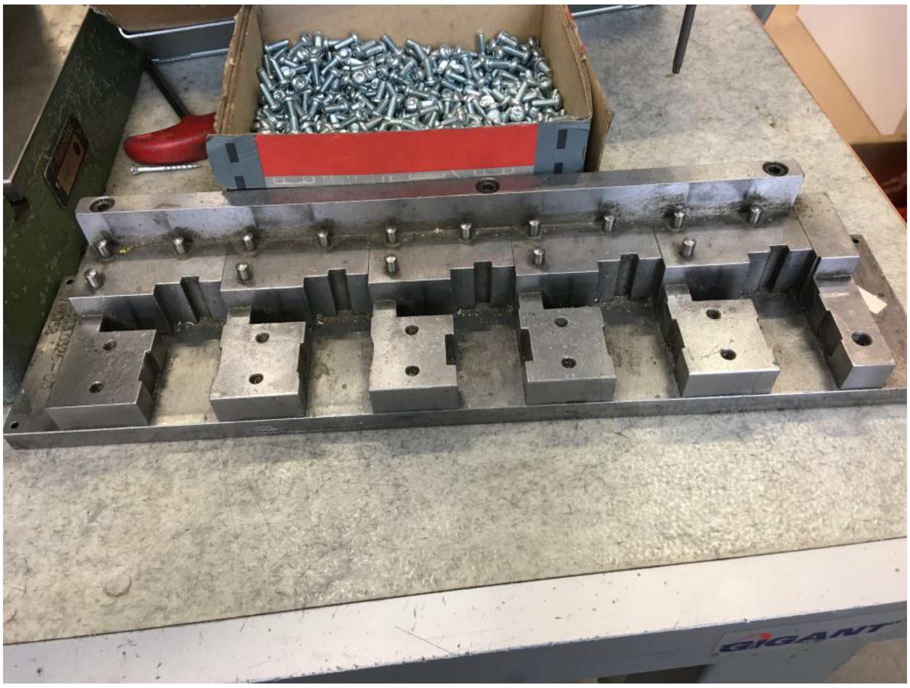


Figure 34. Fixture two (photographed by researcher).

Figure 35. Fixture three (photographed by researcher).

Figure 36. Combined fixtures (photographed by researcher).

The fourth fixture, see Figure 37, is connected to the riveting machine and has a designated workspace in front of the riveting machine. Thus, it is not flexible enough to adapt to other fixtures or workspaces.

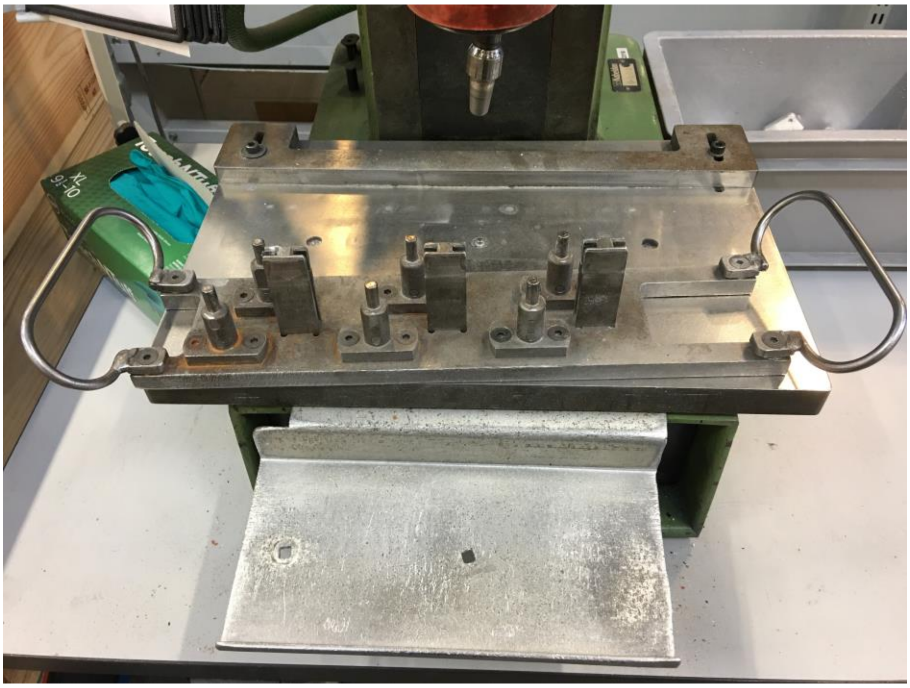


Figure 37. Fixture four (photographed by researcher).

Figure 38. Fixture five (photographed by researcher).

Figure 39. Fixture six (photographed by researcher).

Fixture six, see Figure 39, is eliminated since same work (Task R) can be done within the preceding fixture five in Figure 38. Belonging equipment (1 electric screwdriver) to fixture six is already placed at the neighbouring workstation next to the workstation of fixture five. Hence, it is only more stretched than usual to reach fixture five.

The disadvantages of a combined fixture is having more equipment in a confined working area. There is less room for movement and errors. Hence, the Operator must move confidently and be more flexible in operating the process. Input of parts, but not articles, must be reduced to fit the daily demand.

5.6.2.4 Suggestion 4: Re-design of assembly line

These changes comply with the pull and takt principles when the line is re-designed. Taking suggestion one in consideration the assembly line of Fusegear and Switches is an inspiration for this solution. The assembly line has a takt of 23 and 26 s respectively at five workstations excluding the work of Material Handler and Andon at moving workstations. Product A production is combined with existing assembly line in a one-piece-flow production. Operating the process in a standing position instead of a sitting position or walking position. Where material is fed by Andon and Material Handler.

Task times for tasks A, C, H, J, K and X are not altered to decrease. Therefore, Tasks A and C are executed prior to embarking the one-piece-flow production with Task A preceding Task C. By producing batches of yokes and connectors as it is currently done. Task D is included in the pre-assembly operations due to practical reasons. Because Fixture 1, 2 and 3 is combined and belonging equipment is more efficiently used. Task H is recommended to be done in pre-assembly from the waste analysis in Section 5.6.2.1. Task K preceded by Task J is riveted independently in batches, also prior to one-piece-flow production. Task X is performed once one-piece-flow production is completed, i.e. post-assembly, so Product A is packaged and sent to customer. Task I's task time of five s has been eliminated due to combining it with

Task E. Tasks D, P and W can have decreased task times when the Operator has enough experience. Therefore, only Operators who have extensive experience of the assembly process of Product A operate the one-piece-flow production of Product A. Tasks E, L, M, N, O, Q, R, S, T, U and V have equal to or lower than takt time. Hence, these tasks fit into the one-piece-flow production. Creating a pull system according to the pull principle. Making team members collaborate, dependent of each other, to produce Product A. In synchronisation with pull from the customer.

Subsequently, the movements required by Operator(s) decrease to few steps. To manage housing, socket, box and completed disconnector. The spaghetti diagram of this change in number of movements is unnecessary since actions require no steps for each Operator to perform each task, see Figure 40. Decreasing 39 steps to 14 steps in the value-adding tasks (including change of Tasks B, F, G, I, R, S).

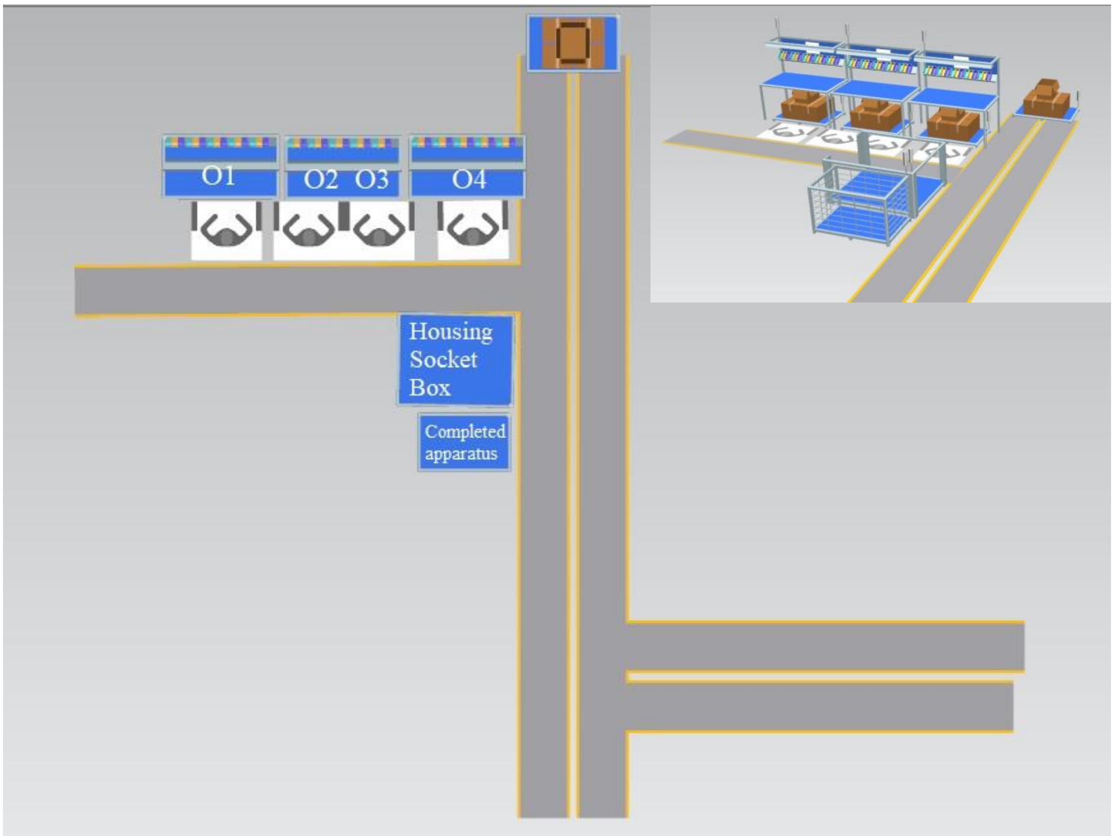


Figure 40. New design of assembly line (constructed by researcher).

The space for sockets, housings and completed disconnector is reduced. By using a multi-level shelf, these parts can be stored next to the workstations on same area based on the benchmarking of logistics and material handling. Only 60 sockets and 60 housings are stored instead of 320 sockets and 130 housings to meet daily demand. Saving 4 m2 of space.

Equipment	Station	Task	Task time	Time left (Takt time = 33 sec)	Task ready (A)
1 torque wrench with compressed air, Fixtures 1-4, 3 riveting machines, 2 screwdrivers with compressed air	I (pre-assembly)	A C D H J K	41 46 30 46 32 60	-263	C, H, J D, H, J E, H, J E, J E, K E, L
Bin	II	E	23	10	L
Fixture 5, 1 electric screwdriver	III	L M	12 16	5	M N, O, P, Q
1 screwdriver	IV	N	18	15	O, P, Q
1 screwdriver	V	O	23	10	P, Q
1 screwdriver	VI	P	33	0	Q
Fixture 6	VII	Q R S T	1 12 2 5	10	R S, T T U
1 screwdriver with compressed air	VIII	U	24	9	V, W
	IX	V	12	21	W
	X	W	29	4	X
compressed air	XI (post-assembly)	X	41	-8	

Total task time is 547 s after alterations. Due to decreased number of steps from 39 to 14, with 0,68 s/step which equals to 17 s. Task H is included in this assembly line design. Three tasks (N, O, P) require the same equipment. Since the tasks are divided between workstations more equipment is needed. Specifically, two new screwdrivers and use of Fixture 6. Due to waiting, the total process time is 634 s (9x33 + 296 + 41) since time left at each workstation is not used.

62% of total task time is executed during pre-assembly and post-assembly. The other 38% is executed in one-piece-flow production with a batch of one. See Figure 41. This suggestion is plausible to have at Fusegear and Switches. With pre-assembly and post-assembly done separately. However, the downside is making the process more complex. Having the Operator doing different tasks at the same workstation can be very demanding. Also, the time to complete a Product A increases with 61 s. Even though the takt time is 20% of the original take time.

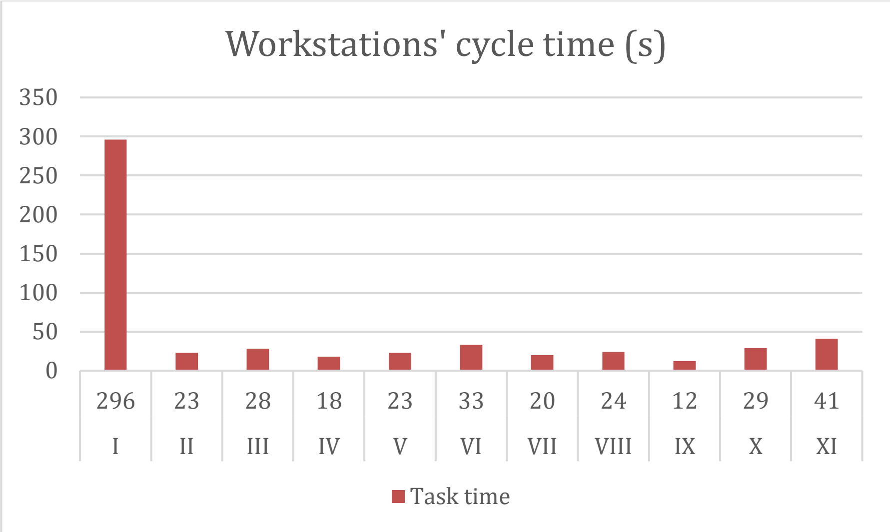


Figure 41. Workstations' CT after alterations (created by researcher).

5.6.2.5 Suggestion 5: Magnet board

These changes comply with the zero defects principle. A checklist of questions is used for the Operator to monitor his or her work. It is mounted on the Operator's arm by strapping the board to the lower arm with an elastic strap. Before moving on to the next operation the Operator is triggered by a question stated on the sheet:

1. For tasks regarding preparations; *"Are you ready to prepare 23 parts and start?"*.
2. For tasks regarding riveting: *"Are you ready to rivet 10 parts correctly?"*.
3. For tasks regarding assembly: *"Are you ready to assemble 27 parts correctly?"*.

In this way the Operator is supported with a way to take ownership of the procedure. S/he feels confident in letting go of previous tasks and following through all tasks in a methodical manner. Making management of tasks easier to have in mind.

The board consists of a thin magnetic plate. There are magnetic sheets, particularly magnetic photo paper to print instructions on, which can be placed on the board. They are kept in place by attaching the sheets to the plate thanks to magnetism in both parts. The sheets are used to convey information. Sheets are printed by using a normal printer. Making it possible for new instructions to be put on the board when the Operator is working on a different process that undergo changes.

The size is dependent on an average-sized arm of an Operator. According to Portman the average wrist breadth is 5.9 cm and 5.2 cm for males and females respectively. According to anthropometric data the elbow-wrist length is 29.0 cm and 26.3 cm for males and females respectively. At a maximum the board has a size of 5x26 cm. However, 4x20 cm is enough to fit an Operator's forearm with a portable checklist.

A disadvantage is the limited space for messages. Having only one page available so to say. As well as writing each message separately and printing it. Adding another process to think about and work with.

5.6.2.6 Suggestion 6: Deviation report

These changes comply with the zero defects principle. Previously, Table 9 has been created. It is a way to report deviations, already practiced by Cabinet Assembly, Surface Treatment and Fusegears and Switches. However, the need for it at Accessories requires reasoning based on theoretical and empirical data collection. Based on zero defects principle, including the measurements this activity can notice deviations in detail. It can act as a quality gate according to EPPC and Q1.1. Providing transparent information as desired and generating good preconditions for gradual positive changes. It changes habits for the Operator to perform tasks calmly with an increased interest in work, treating 3 out of 5 root causes to the LSS project following this feasibility study. Consequently, wastes can be decreased when deviations are factually known.

To get to the next level of excellence the organisation must have a sigma level of 6, hence Six Sigma. Therefore, the organisation is at World-class level when producing only 3.4 defective parts per million produced parts, i.e. 0-1 defect among a year's production output. The report has a disadvantage of additional work. It requires an Operator to actively note deviations. Since it is physically written it cannot be externally controlled so as all fields are completed. Only the Operator has the power to do so regularly. If it was digital, the fields could be interconnected so as the report would not be accepted if all fields were not checked.

Order number		**Amount in order**	**Product name**		**Article number**
Fault		**Rework**	**Scrap**	**Cause of scrap**	**OK**
Article name	**Article number**				
Number of OK without remark					

Table 9. Deviation report (ABB Kabeldon).

5.6.3 Cost-benefit analysis

Costs and benefits of suggestions three, five, and six are not included in this section. Due to lack of comparative data of saved time prior to and post implementation of suggestions. It is also too difficult to produce a forecast of data affecting the efficiency and effectiveness as a result of a Magnet board or a deviation formulary without extensive testing.

It is necessary to prioritise gradual positive changes. To concentrate efforts on the appropriate solutions. As well as declining suggestions that are not worthwhile. The impact-effect matrix is illustrated in Figure 42. The suggestions are prioritised in following order: S1, S3, S4, S6, S2 and S5. Based on an internal comparison of all suggestions.

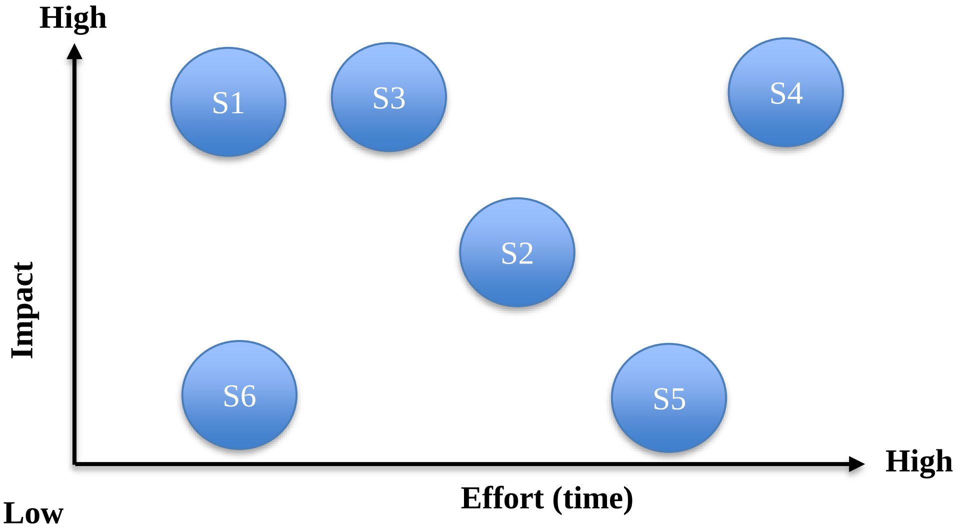


Figure 42. Impact-Effort Matrix (George, 2005: 265).

5.6.3.1 Suggestions 1 and 2: Costs and benefits

What is also necessary to do in a feasibility study is calculating the financial savings of the waste analysis. If an Operator costs the organisation 200 SEK/hour s/he costs 0,055 SEK/s. By saving 95 s, 5,23 SEK is saved for each product made. The historical figure of 3976 units from 2018 can be used to calculate the total amount of savings for a year for the department. This adds up to 20,775 SEK per year. However, 48 s are allocated to another part of the organisations. Thus, overall savings are 47 s of work for each Product A. Converted, savings are 10,278 SEK/year. The difference of costs of pure operations management is a saving of 8%, see Equation 22.

$$Percental\ savings = \frac{Saved\ costs}{Total\ costs} = \frac{0.055 \times 47}{0.055 \times 573} = 0{,}031 \times 100\% = 8\% \quad (22)$$

5.6.3.2 Suggestion 4: Costs and benefits

For this intervention, saved time is 69 s. The saved costs are thereby 15,089 SEK/year. Indicating percental savings, calculated in Equation 23, to 12%.

$$Percental\ savings = \frac{Saved\ costs}{Total\ costs} = \frac{0.055 \times 69}{0.055 \times 573} = 0{,}120 \times 100\% = 12\% \quad (23)$$

However, the torque wrench is used for other products. Therefor it is necessary to invest in a torque wrench dedicated to Product A making the assembly line completely independent from other processes.

5.7 Control

The feasibility study acts a control mechanism for the Process Owner. S/he uses it to decide if a pilot project is necessary to plan. Which is the next stage of Project Management as illustrated in Chapter 4. *Financially*, it is to see if it is possible to deploy the project and following it through. Also, to see how much the actual project can save. *Legality*, laws defined by organisational bodies affect how, and within which regulations the project will exist when it is implemented. EPPC and the Q6 model for this instance. *Operationally*, what the organisation demands reflects the outcome of the methods used in the project. This aspect clarifies if it is possible to undertake actions which affect the operations of the department. *Timely*, a feasibility study generates a time frame for the project and when its activities are to be completed.

Providing a description of the project background controls the decision in the right direction. Making decisions based on evidence, taking all aspects in consideration. With the right aim and objectives, according to a predetermined method. Making the pilot project credible due to the data collected which lead to gradual positive changes. Summarised in a report with data supporting all five aspects.

Several gradual positive changes require control mechanisms to ensure they are implemented appropriately to remain.

1. The tally counter is placed close to the Truck Operator, either in a pocket or in the Truck. Making it accessible and prone to be used.
2. Grease is repositioned in a container at the workstation.
3. Material Handler is communicated with the additional parts that need to be delivered to Product A assembly line. The articles within the warehouse are replaced to be accessible for the Material Handler. Presumably close to other articles that are already delivered to F&S. Material Handler includes these in daily schedules and plans.
4. Standard operating instructions (SOI) are updated with new instructions on how to operate the assembly line. Old instructions are removed.
5. A communication plan with clarification of stakeholders. Describing their roles and responsibilities and the changes that are evident. It is shared as a written document and/or during meetings by the Process Owner. Including both Operators that work together to operate the process during year 2020. Equipment and articles are replaced which is also communicated in the plan. Production Supervisor oversees production by referring to the communication plan. Which is agreed by Co-ordinator/Andon, Maintenance Technician, Safety Representative, Truck Operator, Material Handler, Operators(s), Production Development Specialist and Production Supervisor. To be completed within a timeframe of three months. (Torppa and Smith, 2011)
6. Operator is trained in using combined fixture with equipment and articles.
7. Re-design of workstations is also communicated and explained during a day of Go Gemba within the new assembly line.
8. Magnet board is presented and tested by Operator. Messages are produced for each process. Messages are used as an instrument. To check the ongoing process continuously, responding to the answers. Using the magnet board interactively.
9. Deviation report controls production output and informs deviations, issues and defects. Since it affects behaviour, the Operator must learn to use it by dedicating time for filling it regularly. In the beginning, definitions of fault, scrap, cause of scrap, rework and OK is created. To create a common understanding of deviations of Product A. Which also results in a foundation of deviation control of other process.

5.8 Sustain

The control mechanisms are used regularly to ensure sustainable change. By reinforcing new structures due to the new role of Andon and Material Handler. By reinforcing practices due to alternative or new assembly line design. By reinforcing procedures with combination and adaptation of tasks. The changes are adopted, learnt and managed for three months. When the structures, practices and procedures are reviewed due to gradual positive changes. The review is done during a meeting in which the Process Owner gathers Co-ordinator/Andon, Maintenance Technician, Safety Representative, Truck Operator, Material Handler, Operators(s), Production Development Specialist and Production Supervisor. With successful outcome the team celebrates gradual positive change and enforces the positive attitude towards LSS and Quality Wins in particular.

During the time of implementation, thoughts and emotions about the process is monitored. Documentation and/or meetings are advised for data collection on mistakes. To prevent and make the Product A process mistake-proof. Control mechanisms described in Section 5.7 are used. They are evaluated by respective team member continuously. Outcome of evaluation is shared during Quality Gates, Quality Feedback Loops and in a Meetings Structure. During production evaluation is done with Andon regularly when issues, opinions and praise arise. SOI are updated. To make sure gradual positive change is always documented and available for team members at all times.

In this final stage, the Q6 model is useful to implement due to a standardised, systematic, transparent and simplified way of working. Making management of errors, deviations, defects and issues more efficient. Making operations more effective as was desired from the beginning of this study.

Q1.2 (Andon) is implemented prior to other suggestions being implemented. Thus, as empirical data stated, s/he is included from the beginning. To ensure the proposed suggestions one, two, four and six are pursued consistently. In combination with Q6.1 (Meeting Structure) s/he can also work as a mediator. Between Production Supervisor, team members and other stakeholders that have an impact on production. As in other departments, s/he can also direct the team after a meeting have been held by Production Supervisor, alleviating Production Supervisor's responsibilities. At the same time, going from a manager to a leader as Production Supervisor.

Q1.1 (Quality Gates) and Q1.3 (Quality Feedback Loops) are implemented by using suggestion six (Deviation Formulary) and suggestion five (Magnet board). The process is documented, levelling up to world-class production. The solutions to the problem are also documented separately by Production Development Specialist. To ensure that deviations have been resolved, the solutions are also documented. Within the database, the changes are documented and accounted for.

Q4.1 (Standard Operating Instructions) are already implemented. But the SOI for Product A is updated to fit the changed process. The equipment and articles are described as earlier for each task's execution. Suggestions one, two and five is the Operator held responsible for, continuously incorporating them into usual operations.

6 DISCUSSION

All in all, the study has been rich of learning and grasped the notion of gradual positive change towards the envisioned one-piece-flow production. The journey towards an LSS department has started as a consequence of it. To keep the momentum going and prevent inertia. I was working as an Operator at the company and grasped the opportunity to work on gradual positive change which interested me. Therefore, there was an emergent strategy from the start where I was involved in the complete decision-making process. From finding a suitable problem to address to what should include in the project plan. A creative process was required as well as communicating in a collaborative way and taking ownership of the project. To make the best out of the opportunity and to mitigate risks which were unknown from the start.

Operationally and procedurally, there is little confounding when measuring and mapping the process. All results are used and are aligned with methodology. No additional variables are used in the creation of a SIPOC analysis. However, the categorisation of tasks to respective operation is additional to the precedence diagram. It emphasizes that certain tasks are interrelated. Later, during analysis and improve phase, it was understood that this was not necessary as long as changes within the process were practical. Person confounding is greatest since the Operator's work experience significantly affected results. The measurements in seconds can be fairer if several Operators' work is investigated. (O'Leary, 2017: 66-70)

Both Lean and Six Sigma are adopted. Lean is expressed more clearly. Due to measurement and analysis techniques used. Founded on the four principles which are followed to achieve goals for each part of the process. However, the method is based on Six Sigma. The systematic approach and the holistic problem evaluation are inspired by Six Sigma philosophy. Focusing on learning, operations, quality and people. Using a triangulation to find data. Which makes progress, throughout the project, credible, truthful as well as realistic. Thus, encompassing many parts of the problem area. Which was very useful when suggestions for gradual positive change were produced. The suggestions were produced relatively fast. They could be efficiently argued for. Even though some areas could be elaborated such as ergonomics, Quality Wins and its Q6 model, type of assembly line, silent organisation as well as trap of success. Hence, research questions and demarcations kept me from going astray and loosing focus.

On one hand, the methodology of LSS is accurate and clear to work by. Navigation of the problem solution process is quickly done. It is logical and decreases deviations due to subjectivity, lack of motivation to follow through, insufficient data and incorrect use of data. A broad set of tools and techniques for each stage is available. Making the process efficient and effective if adapted correctly. On the other hand, it is time-consuming and not all charts, figures and tables is useful on the long run. Most of the generated data is a way of visualising of how it is, which do not always help the team go forward. Instead, it can lead to communicating the same subject in different ways.

The research questions have been answered. Assembly line balancing was also explored during interviews, surveys and observations. Which added to and enforced the theoretical explanation. Gradual positive change towards one-piece-flow production has been explored from the organisational point of view and the academic point of view. To discover an appropriate way forward. It is difficult to clearly decide whether it is necessary to do so for the production of Product A. With a glance on the other products' takt time at the organisation it is safe to say that at least 50% can be adapted to a one-piece-flow production from this perspective. Hence, the department can benefit from going from batch production to one-piece-flow production. To do so with Product A and other products that requires more time and variation in time for each task is doubtful. Especially if the volume is not high enough and the equipment and machines are not practical to fit a one-piece-flow assembly line.

A pilot project can be successful due to several reasons, see Table 10. Mainly, 12 reasons according to theoretical data and 15 reasons according to empirical data. As discovered, for ABB Kabeldon and Accessories in particular an LSS project is regarded as possible by team members. The majority responded positively about the future. Having a positive stance about wanting to change. They have faith in LSS projects and their ability to make it work practically. They also have knowledge about LSS, enabling a manager to communicate with them. Critical success factors are important to emphasize in order to gain trust in the philosophy and change the organisation for the better through a proactive approach to gradual positive change. However, it is worth considering the magnitude of the change. Instead of providing a complex solution it may be wiser to implement smaller changes until the final solution is practiced. For instance, suggestion five is a steppingstone towards a technical device, e.g. a tablet.

Success factors (theoretical)	**Success factors (empirical)**
Top management commitment	Cross-functional management
Training and education	Learning and feedback
	Guide or tutor
Understanding equipments and techniques	Equipped operations
	Instructions
Customer focus	
Communication: relevant data communicated	People engaging with each other and his or her work in a healthy way
Organisational culture	Changes for the better and easier work
People	Clear roles and responsibilities
	Having fun
	Having trust in the process
Employee involvement	Dedicated team of people exclusively for larger change initiatives
Operators concentrating and prioritising the project to adapt to the changes	
Teamwork	Collaboration
Supplier focus	Applying it to a relatively complex process
	Simplifying the product with less parts
Organisational infrastructure	Being prepared

Table 10. Critical success factors (compiled by researcher).

The number of interviewees provided enough information for me to make use of in this study. Most of theory is covered and empirical data provide multiple perspectives of the problem. From different departments with different amount development. From team leaders' point of view who have insight in an Operator's work conditions, the managers approach and the vision and strategy of the department. However, with more interviewees the study could be confidently generalisable.

As results show, there is a consensus of responses in few areas. The responses deviate from each other, considering different aspects of the question(s). The questions may also have been too broad, focusing on several areas of the problem instead of only one. However, the role of a feasibility study is to provide a basis for decision-making. Therefore, it is appropriate to create connections to operations, people, quality and the assembly line to produce realistic suggestions. (Tickle-Degnen, L., 2013; Sahadev Roy and Momin Mukherjee, 2017)

In a nutshell, the six solutions are feasible. After validation of each suggestion with stakeholders. Gradual positive change is proven to be possible based on Operators' and team leaders' statements, observations on the operations, financial results of changes and the correlation with organisational objectives. After analysing the results, that is. The same goes for one-piece-flow production. At length, the five aspects are considered which presuppose a condition for success. The solutions complement each other and can be implemented independently according to the prioritisation made in Section 5.6.3.

Technically feasible

Product A should be incorporated with other processes at the department. To make better use of equipments, workspaces and production output. Customers can benefit from technical changes of non-standardised plastic material, poor quality of housing and relatively many parts. Enabling a way to develop a new Product A as simultaneously adapting it to operations of other accessories. This requires an investigation of product development.

Based on observations, equipments and machines are movable and flexible. E.g. screwdrivers have bits that are interchangeable. The parts are loose and can be provided in smaller batches to meet customer demand. Suggestion four implicate a new torque wrench. An investment is required to do so. Beyond these changes, there are no necessary, technical changes according to measurements, observations and requirements of one-piece-flow production. The proposed changes are mostly operational.

Financially feasible

Half of the tasks to produce a Product A are significantly more time-consuming than the other half. A combination of one-piece-flow production and batch production is viable with a higher volume, even higher than the prognosis for year 2020. Thus, the paradox of financial savings versus customer demand arise. Financial savings of 8% due to suggestions one and two. As well as, financial savings of 12% due to suggestion four improve and make the process more valuable. But it is more urgent, if the prognosis for year 2020 realises, to meet proposed takt time. So as two Operators can operate the whole process. Thus, labour is doubled, and workstation is re-designed with an experienced Operator. However, it is favourable, to start with proposed control mechanisms, mistake-proofing and managerial communication to increase effective and efficient production. To meet customer demand and takt time whilst saving money.

Legality feasible

The ordered way of working, i.e. Q6 model inherent to Quality Wins and EPPC on a greater level, is sought to be followed. The rules bound to each intervention is followed to align departmental strategy to organisational strategy. Q1.1 (Quality Gates), Q1.2 (Andon), Q1.3 (Quality Feedback Loops), Q4.1 (Standard Operating Instructions) and Q6.1 (Meeting Structure) are five out of eleven possible interventions to act upon. Thus, half of the Q6 model is enabled as a result of a pilot project based on this feasibility study.

However, other aspects of production is important to define, understand and correlate to the project. To make sure it is flexible and suitable for other processes at Accessories. All interventions except for Q4.1 will also benefit other processes at Accessories. Andon will learn to do the same work independent of a process and its product. Meetings facilitate lessons learned that can be imitated in other processes or inspire new processes. Quality Gates and its activities can also be used for other operations and be reiterated independent of process. The same goes for Quality Feedback Loops. Making the legality aspect meaningful and useful for the Operators in particular. Management, learning, communication, culture, resources and the organisation do all benefit from the changes. In a systematic manner, working with facts and statistics to generate gradual positive change towards one-piece-flow production. By managing driving and restraining forces on a regular basis. Letting people express their opinions on different matters and documenting them to make work more meaningful.

The Q6 model requires dedicated time for preparations, training, education and management. An Andon or Operator needs to deviate from production to partake in the change process at start. Four out of six suggestions suit the Q6 model. Suggestions three do not fit with any of the chosen Q6 interventions. Suggestion three is a technical change on fixtures which is not directly connected to product quality. But rather speed of operations. Similarly, suggestion four is a re-design of the assembly line leading to different layout, sequencing of tasks and work content. Which does not necessitate systematic approach since the changes are non-recurring.

Operationally feasible

Since there are team members who can be consulted there is enough resources aiding the Process Owner. To change operations and adapt them to the new philosophy of LSS. The suggestions entail changes to behaviour, work structure, work content and an understanding of departmental vison as well as strategy. They increase responsibilities and requires development of personal qualifications to operate the future state of operations. A balanced assembly line indicates gradual positive change. Avoiding comprehensive changes that can be overwhelming whilst operating according to business-as-usual. E.g. a combined fixture makes work content more condense. A magnet board and deviation formulary clarifies what is actually done. It's additional tasks that integrates production with management. Making operations seen objectively from both sides, by both white-collar and blue-collar team members. These incremental changes to operations leads to a workbench that is more concise. Articles being more accessible. Increasing trust in team members ability to count parts by decreasing duplication of work. They also pioneers one-piece-flow production which is automated or semi-automated.

Timely feasible
The timeframe of three months is acceptable since it is within the warranty timeframe of the organisation. The warranty timeframe is up to one year. During which the project is completed, handed over and closed, to relief resources for other projects. Within this timeframe the team and their process of Product A assembly undergoes changes according to gradual positive change. Meanwhile the Q6 model requires more time to undergo the change process. From unfreezing current OMS with its structures, procedures and practices. To changing it and freezing the new way of operations based on LSS (Hayes, 2007: 81). It is harder to foresee how much time. Due to the complexity of individual and collective learning at Accessories. There are other processes that are operated. Other accessories and projects affect the possibility to use time efficiently without wasting it without development. However, the results are lasting taking success factors in consideration. Once it is done, the project is terminated, and the process can continue without further investments. Unless major changes are needed due to greater demand on Product A or other demands from the market.

Subsequently, it is worthwhile to mention if the project is culturally feasible as prescribed by Marzagao and Carvalho (2016). Galli (2018) state that *"people are the changes, not the models, and people will only change if they see and feel the need to do so."*. As inclined by the Operators and Co-ordinator/Andons this is an aspect which require soft skills of management, to apply one of the success factors. Namely, changes due to the project being for the better and making work easier. Even though work becomes easier and it is better, the new state is frozen once it is the new status quo. Which is inevitably subjective.

Furthermore, this study makes an important lesson learned apparent. Data is vital for a successful implementation of LSS. People have disparate understanding of LSS, reasons for gradual positive change and one-piece-flow production. Most are engaging in producing products with high quality but lack organisational structure on how to improve it. Data simplify and make decision-making more realistic. Focusing knowledge on specific issues. Proving improvements and problems objectively based on facts. Affecting the whole organisation and its structures, procedures, norms, practices and beliefs when processing data. This also calls for appropriate methods to efficiently manage data. With expected and unexpected results that fulfil needs.

6.1 Credibility

The study is credible by evaluating and ensuring validity, generalisability, reliability and transferability. Can the research be verified? In order to satisfy the basic needs of the organisation and the academic profession the study must be credible. The organisation needs suggestions for improvements based on evidence. The academy needs knowledge to be integrated critically and systematically.

6.1.1 Validity

The reason it is internally valid is because the study is based on information provided by ABB Kabeldon. The measurements and mapping are done on an existing and real process. The study contains data that are deducted from people operating the process and managing the department amongst others. Explanation of the process is in detail and the analysis is based on it. The chosen tools are widely used by professionals and academics throughout the manufacturing industry. The problem is prompted by issues within the company to manage change. Therefore, the true state of affairs is described from an organisational, academic and engineering perspective.

6.1.2 Generalisability

In several ways the study is externally generalisable. The data have been collected independently without affecting each other prior to collection. It is interesting that empirical and theoretical data intersect in all matters. That is in terms of operations, people, quality and assembly line balancing. The study is based on previous researcher's work in similar settings. The assembly line exists throughout the manufacturing industry. Therefore, the study is understood independent of reader working in any part of the industry. The results, analysis and discussion can be used generally for many assembly line balancing problems. Especially SALB-2 problems. To go from a batch production to one-piece-flow production. It is due to these findings that the survey is generalisable in another production setting or manufacturing organisation. There restrictions are most likely due to the size of the organisation, being a small organsation where Accessories is one of the smallest departments.

6.1.3 Reliability

As discussed, the measurements could be more precise by measuring several Operator's practices. The research technique is meticulously followed to provide accurate and traceable results. A timekeeper, production software, voice recorder, pen and paper were used. Therefore, the instruments, including the equations, can be used in similar settings and still have the same results. With exception for pen and paper, whereas a researcher can record the situation differently. However, if there are no bias or errors the results would be the same. Participants have bias and as was understood in the interviews, surveys and observations they had mostly a positive attitude about something they did not know much about. Lacking in critical observations, bias deters objectivity from a participant.

Since I am relatively new at the company and unknown to Accessories bias is minimal. I have no personal nor professional attachments and have been able take on a consulting role to work towards the project's aim and objectives objectively. As a result, the study makes use of facts from reliable sources and team members' opinions. Which coincides with ABB Kabeldon's desire to have access to theoretical grounding besides company data.

6.1.4 Transferability

The research can be applied to other situations. Particularly when applied to case studies such as this study. A feasibility study includes predetermined aspects of the problem solution process. As discovered when benchmarking, solutions from other departments are transferable to Accessories. Even though the products, work content and tools are different. If research would be conducted in a hospital, it would be possible to explore how a doctor's operations could be made more effective and efficient to decrease deviations such as damages to a patient or waste such as blood usage to perform an operation. Therefore, with precise aim and objectives, problem description and appropriate theory as well as empiricism it is transferable. The "skeleton" can be used in other situations including the methodology and tools for results and analysis.

7 CONCLUSION

In conclusion, the solutions to the problem are two-sided enabling team members to embrace one-piece-flow production. On the one hand, Product A and its assembly line is approached with six suggestions for gradual positive change. By balancing the assembly line, re-balancing it, using a combination of fixtures, re-designing the assembly line, using a magnetic board and reporting deviations. Partly by balancing the assembly line and partly by complementing it with technical, practical and operational solutions. On the other hand, the five interventions of the Q6 model is applied systematically. Applying tools to produce evidence-based decision-making on a daily and/or weekly basis. When gradually changing operations, processes, networks, people and the department of Accessories for the better. The suggestions are implemented together in an LSS project or separately incorporated into business as usual.

To succeed with LSS projects it is critical to consider eight values: commitment, understanding, experience of team members, collaboration, prioritisation, clarity, purpose and organisation.

The feasibility study is found to be credible in terms of four elements. For the reader, company and academy to find it worthwhile engaging with the study. Which can be used for organisational and academic progress.

8 FUTURE RESEARCH

There are more possible solutions due to the immaturity of the department in relation to more mature LSS departments within the organisation. These solutions may be more important to utilise or to begin the LSS journey with. Therefore, the department and its team members are advised to further investigate possible problem areas that have not been detected in this study. Subsequently, finding more solutions that can be analysed and prioritised.

Other consultants or students may have the possibility to continue this research. He/she can use following hypothesis:

- ❖ All processes have appropriate amount of changeover times for one-piece-flow production.
- ❖ There are too many defects produced without a buffer.
- ❖ There are certain competencies required to operate one-piece-flow production.

Last but not least, an exploration of technical devices can be done. To understand the compatibility of each device with the production system and its processes. How virtual reality (VR) supports the learning process of an Operator. To learn new or change behaviour, work content and work setting. How artificial intelligence (AI) can replace, serve or collaborate with an Operator in certain operations. How augmented reality (AR) can make visualisation and analysis of a process and its operations more flexible in terms of physical location, interference with production and interactions with machines and equipment.

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APPENDICES

Appendix I: Information Letter

Information letter

Hi!

My name is Berwa Kader and I am a student within the master's programme International Project Management at Chalmers University in cooperation with Northumbria University in Newcastle upon Tyne, England. During the autumn of 2019 I am doing my degree project. To be able to do this I need participants and hope that You can help me with this. My dissertation is a feasibility study which explores the opportunity of implementing an Operations Management System according to Lean Six Sigma (known as Quality Wins) within the department of accessories at ABB AB. In particular, the disconnector Product A will be used as an example.

If You choose to participate in the feasibility study, You will be asked to answer a set of questions in an interview at desired location and time. For the interview there is no need of preparations. The interview will approximately take 30 minutes to complete. The interviews will be recorded for later transcription. When the study is fully examined and archived the data collection will be obstructed. I will follow the ethical aspects with regards to demands on integrity, consent, information and confidentiality. This means that the interview will be deidentified and treated confidentially with utmost care and respect of the individual. Your participation as participant can be cancelled and is voluntary.

If You choose to participate in this study, You will be contacted by me to set up a place and date for the interview.

If You have any questions about the study or if You want more information, feel free to contact me through e-mail. You also have the possibility to contact my Supervisor Mathias Gustafsson at Chalmers University, alternatively Fredrik Karlsson at ABB AB.

Thank You for Your time and Your cooperation.

Kind regards,

Berwa Kader
berwa.kader@icloud.com

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Supervisor (ABB): Fredrik Karlsson
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Appendix B: Interview Consent

Skriftligt samtycke

Jag har härmed tagit del av syftet med studie. Dessutom är jag ense om vad mitt deltagande i studien betyder. Jag är ense om att intervjun kommer att spelas in men att materialet kommer att kasseras efter uppsatsens godkännande.

Jag är även ense om att jag kan avbryta mitt deltagande i studien när som helst utan vidare motivering.

Härmed samtycker jag till att vara deltagare i denna intervju.

Ort, datum:

____

Namnteckningar

Intervjuperson:	Intervjuare:
____________________________	____________________________
	Berwa Kader

Written consent (in English)

I have hereby taken part of the purpose of the study. In addition, I approve of what my participation of this study entails. I approve of the interview being recorded but that the material will be discarded after the essay's approval.

I also approve that I can cancel my participation of the study whenever without further notice.

Consequently, I approve to participate in this interview.

Signed by interviewee and interviewer during the stated date at the shared location. (see above)

Appendix C: Interview Guide

Introduction

1. What department do You work within?
2. How long have You worked as an operator at ABB AB?
3. How come You are working with assemblies in Alingsås?

Organisation and responsibilities

4. Do You know how the organisation is structured at Your department? If yes, can You describe it?
5. What are Your main work activities?
6. Do You have possibility to suggest improvements? If yes, how does the organisation make it possible? If no, is there something You are missing?
7. Do You have space to manage Your work on Your own way?

Quality Wins/LSS project

8. What does Quality Wins mean for you?
9. Can You tell me something good about Quality Wins?
10. Can You tell me something less good about Quality Wins?
11. How can the department succeed with Quality Wins?
12. Why is it necessary to implement an LSS project?
    a. Why is it like that?
    b. Why do you think it is so?
    c. Why?
13. What do You think makes changes to the assembly line long-lasting?

One-piece-flow production

14. What do You believe is the difference in making batches and making one piece a time? For example, disconnector Product A.
15. What can help the department moving towards a one-piece-flow production?
16. What obstacles do You see of changing towards one-piece-flow production?

Gradual positive change

17. What do You think can be obstacles of learning new approaches? For example, a new way of assembling a product by using other tools.
18. What facilitates for You to learn an operation?
19. Is there anything that can facilitate for You to manage changes? If yes, what?
20. How do you receive change?
    a. Do You wait on instructions or do You search for what to do? For example, when a product is used to balance an assembly line.
21. What driving forces do You see regarding change in Your work? What would make You want to follow new rules, routine and/or ways of working?
22. Can You mention a few factors that could help You to adapt to new routines?
    a. For example, colleagues, work material, team leader, inhouse education?

Termination

23. Is there something You would like to add?
24. Can I come back to You with possible questions if it is necessary?

Appendix D: Survey

Managing improvements according to Quality Wins/Lean Six Sigma

Hi!

My name is Berwa Kader and I am a student of International Project Management at Chalmers University of Technology in Gothenburg. I am looking into Quality Wins/Lean Six Sigma at the Accessories department. Your participation is of course completely voluntary, and your answers will be treated completely anonymously.

Your feedback is important. It supports the organisation with an overview of what team members think. The answers will facilitate understanding of what is important with improvements, its reasons and consequences connected to Quality Wins/Lean Six Sigma. It hopefully helps You to reflect on Your own thoughts and opinions. Possibly with co-worker(s) that also have participated.

1. I am working in following department(s). Mark all departments You work within.

☐ Press ☐ Surface Treatment ☐ Powder Coating
☐ Barrel and Rack lines ☐ Cabinets Assembly ☐ Fusegear and Switches
☐ Accessories ☐ Material Handling Other (please specify): ___________

2. Mention three things that eases improvements of production towards one-piece-flow.

1: ____
2: ____
3: ____

3. What do You think about improvements of your work center? Describe this.

____
____

4. I want to change the way I work. Mark one.

☐ Strongly agree ☐ Disagree
☐ Agree ☐ Strongly disagree
☐ Neither disagree nor agree ☐ Do not know

5. Working with one-piece-flow production is better than working with batches. Mark one.

☐ Strongly agree ☐ Disagree
☐ Agree ☐ Strongly disagree
☐ Neither disagree nor agree ☐ Do not know

6. Learning/training/education is an important part of change. Mark one.

☐ Strongly agree ☐ Disagree
☐ Agree ☐ Strongly disagree
☐ Neither disagree nor agree ☐ Do not know

7. I believe Quality Wins can improve my work situation. Mark one.

☐ Strongly agree
☐ Agree
☐ Neither disagree nor agree
☐ Disagree
☐ Strongly disagree
☐ Do not know

8. I lack knowledge about Quality Wins. Mark one.

☐ Strongly agree
☐ Agree
☐ Neither disagree nor agree
☐ Disagree
☐ Strongly disagree
☐ Do not know

9. Using Quality Wins can make a big difference for me and my work. Mark one.

☐ Strongly agree
☐ Agree
☐ Neither disagree nor agree
☐ Disagree
☐ Strongly disagree
☐ Do not know

10. It is important for management to pay attention to progress by rewarding good results and correcting bad results. Mark one.

☐ Strongly agree
☐ Agree
☐ Neither disagree nor agree
☐ Disagree
☐ Strongly disagree
☐ Do not know

If You have additional comments You can readily write these below.

____

____

Thank You for taking Your time to answer this survey!